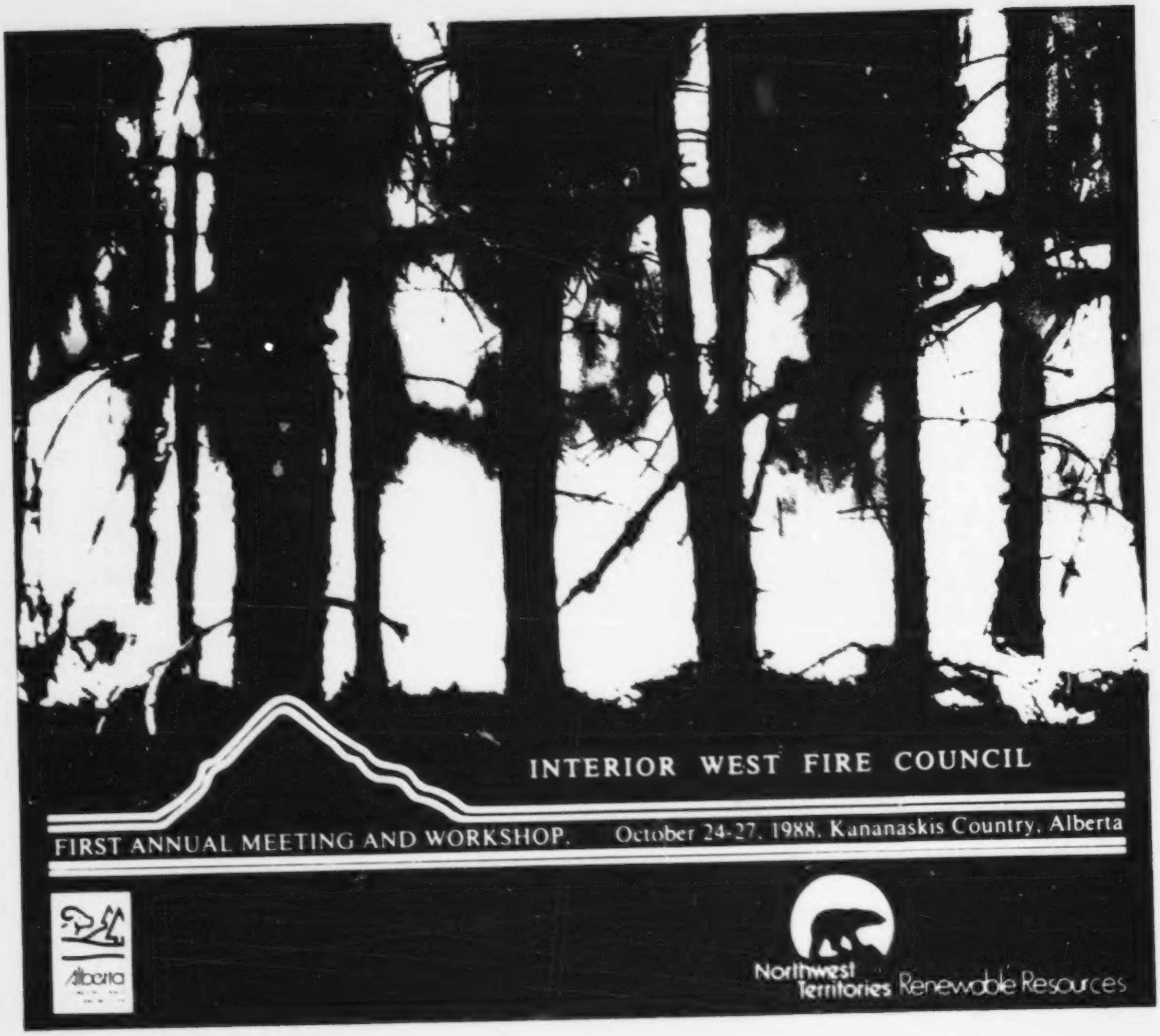
The art and science of fire management

M.E. Alexander and G.F. Bisgrove

Northwest Region • Information Report NOR-X-309


INTERIOR WEST FIRE COUNCIL
FIRST ANNUAL MEETING AND WORKSHOP. October 24-27, 1988, Kananaskis Country, Alberta
Alberta
Northwest Territories Renewable Resources

Forestry Canada
Forêts Canada

THE ART AND SCIENCE OF FIRE MANAGEMENT

Proceedings of the
First Interior West Fire Council Annual Meeting and Workshop
Kananaskis Village, Alberta,
October 24-27, 1988

M.E. Alexander[1] *and G.F. Bisgrove*[2]
Technical coordinators

INFORMATION REPORT NOR-X-309

FORESTRY CANADA
NORTHWEST REGION
NORTHERN FORESTRY CENTRE
1990

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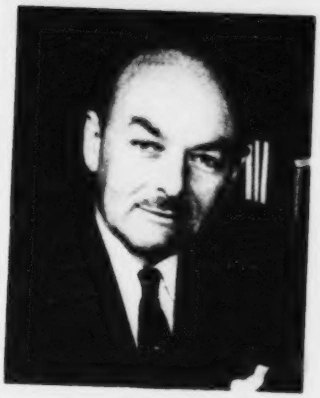
ABSTRACT

A workshop dealing with the art and science of fire management was held October 24-27, 1988, at Kananaskis Village, Alberta, in association with the first annual meeting of the Interior West Fire Council. A total of 36 invited presentations were made, preceded by a keynote address and followed by a workshop summary, involving four technical sessions: fire management problems and opportunities; fire research programs in support of fire management decisions and solutions; the role of new technologies, analytical systems, and support services in fire management activities; and fire management actions and practices. The luncheon and banquet addresses, poster session abstracts, and field trip notes are also chronicled.

RÉSUMÉ

Un atelier portant sur l'art et la science de la gestion des incendies s'est tenu du 24 au 27 octobre 1988 au village de Kananaskis, en Alberta, lors de la première réunion annuelle de l'Interior West Fire Council. Le tout a débuté par un mot de bienvenue suivi de 36 exposés qui avaient été sollicités et d'un atelier comportant quatre séances techniques: problèmes et possibilités de gestion des incendies; programmes de recherche sur les incendies à l'appui des décisions et des solutions en matière de gestion des incendies; rôle des nouvelles technologies, des systèmes d'analyse et des services de soutien lors des activités de gestion des incendies; et activités et méthodes de gestion des incendies. Le rapport fait également état des discours prononcés lors du déjeûner et du banquet, résume les séances de présentation d'affiches et présente des notes sur les excursions qui se sont déroulées.



DEDICATION

Jack S. Barrows
1911-1989

> *. . . there is one overriding challenge to fire management: that of maintaining full respect for the power of fire and the effects of this power on both wildland environments and the people who live and work in these environments*[1].

Forest fire research and management lost one of its most staunch supporters when Jack Barrows passed away on February 25, 1989. Jack was one of the founding members of the Western Forest Fire Committee of the Western Forestry and Conservation Association as well as the Intermountain Forest Fire Research Council.

Jack received a Bachelor of Science degree in forestry from Colorado Agricultural and Mechanical College (now Colorado State University) at Fort Collins. Following graduation, he began his professional career with the U.S. National Park Service, serving in a variety of positions from 1935 to 1942.

In 1946, after he served in the U.S. Army during World War II, Jack joined the U.S. Forest Service at the Northern Rocky Mountain Forest and Range Experiment Station in Missoula, Montana. Jack's early work in fire research reflected his strong interest in advanced technology, particularly the use of aerial fire control methods, including research on chemical fire retardants and water bombing. Jack was also one of the pioneers in lightning research. In the early 1950s, he wrote *Forest Fires in the Northern Rocky Mountains* and *Fire Behavior in Northern Rocky Mountain Forests*, which have remained classics to this day.

During the 1950s, Jack was a driving force behind the establishment of the Northern Forest Fire Laboratory (now the Intermountain Fire Sciences Laboratory). In 1960 he became the Missoula laboratory's first chief, directing research projects on lightning fires, infrared fire detection and mapping, forest fuels, fire behavior, and control of forest fires. In 1964, Jack was appointed Director, Division of Forest Fire and Atmospheric Sciences Research, in Washington, D.C., where he continued to be a strong advocate of wildland fire research and the application of new technology in fire control. Following his retirement from the U.S. Forest Service in 1972, Jack returned to his alma mater as a full-time lecturer. Following retirement from CSU in 1978, he served as an expert witness in a number of court cases involving fire control issues and had been working on a book about his experiences in fire management and fire research. His numerous honors included CSU Honor Alumnus (1958) and the U.S. Department of Agriculture's Superior Service and Meritorious Achievement awards.

The above photograph, taken in 1988, was kindly provided by Jack's good friend, John H. Dieterich.

Martin Alexander

---

[1] Barrows, J.S. 1977. Guest editorial: the challenges of forest fire management. Western Wildlands 4(1):55-57.

PREFACE

The last joint session of the Intermountain Fire Council and Rocky Mountain Fire Council was held at Jackson, Wyoming, October 20-22, 1987. One of the major decisions made by the members of both councils at the business meeting was the consolidation of the two councils into one council to be known as the Interior West Fire Council (IWFC). The principal goal of both these organizations has been the general improvement of wildland fire management practices through participation in a central forum of member agencies. The current council members include (in alphabetical order): Alberta, Colorado, Idaho, Kansas, Montana, Nebraska, North Dakota, Northwest Territories, South Dakota, Utah, and Wyoming. The first annual meeting and workshop of the IWFC, hosted by the Canadian component of the council was held October 24-27, 1988, at the Kananaskis Village, 75 km west of Calgary, Alberta. Two previous meetings of the Intermountain Fire Council were held in Alberta—Edmonton in 1978 (Quintilio 1979) and Banff in 1983 (Dubé 1985).

The theme of the 1988 meeting/workshop was *The Art and Science of Fire Management*. The Canadian Committee on Forest Fire Management recently defined *fire management* as follows (from Merrill and Alexander 1987):

> The activities concerned with the protection of people, property, and forest areas from wildfire and the use of prescribed burning for the attainment of forest management and other land use objectives, all conducted in a manner that considers environmental, social, and economic criteria. Fire management represents both a land management philosophy and a land management activity. It involves the strategic integration of such factors as a knowledge of fire regimes, probable fire effects, values-at-risk, level of forest protection required, cost of fire-related activities, and prescribed fire technology into multiple-use planning, decision making, and day-to-day activities to accomplish stated resource management objectives. Successful fire management depends on effective fire prevention, detection, and pre-suppression, having an adequate fire suppression capability, and consideration of fire ecology relationships.

The 1988 IWFC fire management conference consisted of four half-day technical sessions involving 36 invited presentations dealing with

- fire management problems and opportunities;
- fire research programs in support of fire management decisions;
- and solutions;
- the role of new technologies, analytical systems and support services in fire management activities; and
- fire management actions and practices.

The program also featured vendor/exhibitor displays, a poster session, a luncheon and banquet with distinguished speakers, and a half-day field trip to Banff National Park.

We wish to extend our sincerest appreciation to the speakers (and their coauthors, as applicable) and the moderators for their obvious contributions to the meeting and workshop. Several speakers were still able to prepare and make their presentation inspite of an extremely heavy workload associated with a major fire season in the western United States in 1988.

The sponsors of the 1988 IWFC annual meeting and workshop are acknowledged elsewhere in these proceedings. The support of Dave Kiil, Regional Director General, Forestry Canada[1], Northwest Region, and John Benson, Director, Forest Protection Branch, Alberta Forest Service, is gratefully acknowledged. The following Alberta Forest Service, Alberta Forest Technology School, Canada Parks Service, and Forestry Canada employees also deserve credit for a successful gathering at Kananaskis:

- Keith Peters, Cathy Bartko, Sirri Paldrok, and Elaine Schiewe for serving at the registration and information desk.
- Robert Young, Charles Ogilvie, William De Groot, and Kenneth Collett for coordinating the audiovisual arrangements and for other support functions.
- Murray Maffey and Richard Smith for their assistance with the poster session and numerous other tasks.
- Owen Bolster, Leo Drapeau, George Benoit, and Frank Nuspell for coordinating at the vendor/exhibitor displays.

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[1] At the time of the 1988 IWFC annual meeting and workshop, the Canadian Forestry Service (CFS) came under Agriculture Canada. In February 1990, the CFS received official status as a full department of forestry in the Government of Canada. Thus, the use of CFS at various locations within these proceedings simply reflects the terminology as of October 1988.

- Brent Seeley for assisting with the student accommodation at the Kananaskis Forest Experiment Station.
- Joyce Simunkovic, Shamy Ratansi, Elaine Schiewe, and Robert McAlpine for word processing.
- Brenda Laishley and Brenda Boughton for editing of the proceedings, and Dennis Lee for layout of the proceedings.

We were especially pleased to have been involved in planning the first annual meeting and workshop of the Interior West Fire Council. During the opening ceremonies, an inscribed brass bell was presented to the council's permanent secretary-treasurer Jack Peters on behalf of the local host organizations in Canada to mark the occasion and for use in future council gatherings. We would like to think that this symbolic gesture rings in a new era in fire management.

Martin Alexander
Forestry Canada

Gordon Bisgrove
Alberta Forest Service

Technical coordinators

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THE AUTHORS

MARTY ALEXANDER is a Fire Research Officer with Forestry Canada located at the Northern Forestry Centre in Edmonton, Alberta, where he is the study leader responsible for fire danger rating/fire behavior research and development in the Canadian prairie provinces and Northwest Territories. He received his B.Sc. (1974) and M.Sc. (1979) degrees in forestry from Colorado State University. Marty has worked for Forestry Canada since 1976, initially at the Great Lakes Forestry Centre in Sault Ste. Marie, Ontario, before tranferring to his present position in 1981. He worked seasonally in fire management and research for the U.S. Forest Service from 1972 to 1974 on the Bighorn and Nez Percé national forests and at the Rocky Mountain Forest and Range Experiment Station.

GORDON BISGROVE is the Manager in charge of wildfire and aviation operations with the Alberta Forest Service's (AFS) Forest Protection Branch and is located at the Provincial Forest Fire Centre in Edmonton, Alberta. He received a technician diploma from the Alberta Forest Technology School. Gordon has worked in various positions for the AFS since 1963 on the Peace River, Bow-Crow, Edson, Footner Lake, and Slave Lake forests. He was a Forest Protection Officer for 9 years prior to assuming his present position in 1986.

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

CALL TO ORDER AND WELCOME

1988 General Chairman:

John E. Benson
Forest Protection Branch
Alberta Forest Service
Edmonton, Alberta

Good morning, ladies and gentlemen, and welcome to Kananaskis Country. My name is John Benson and I will serve as your general chairman for the next 3 days of activities. I would also like to welcome all of you to our first annual meeting and workshop of the Interior West Fire Council. This is a first! You will recall that at last year's joint Intermountain Fire Council-Rocky Mountain Fire Council meeting in Jackson, Wyoming, the two councils decided to join together and form the Interior West Fire Council. It is with pleasure that we, here in Canada, host the first annual meeting and workshop of the new council.

I would now like to acknowledge the sponsors of this first annual meeting and workshop of the Interior West Fire Council. They are:

- Government of Canada
  - Forestry Canada
    - Northern Forestry Centre
    - National Headquarters
  - Canadian Parks Service
    - National Headquarters
    - Western Region Office
    - Banff National Park
- Government of Alberta
  - Alberta Forest Service
- Government of the Northwest Territories
  - Department of Renewable Resources
- Society of American Foresters, Fire Working Group

All of the people associated with the program and local arrangements committee have worked very hard to put on what we hope will be a truly memorable affair. If it is anything like the previous Intermountain Fire Council meetings in Alberta, I'm sure you won't be disappointed.

I'm pleased to see such a broad spectrum of people here today. We have educators, researchers, consultants, vendors, and operations people. All members of the wildland fire community! This is much like a fire triangle in the sense that without research and training, and without equipment development, it can be very tough in the fire business. We need all parts of our community working together to effect proper fire management. I have also had the chance to review the list of registered participants. We have people here from British Columbia to Newfoundland and with representation from almost every province in Canada. We have people from Arizona to Inuvik in the Northwest Territories. We even have a gentleman here from Hobart, Tasmania. A very broad spectrum indeed!

I hope you enjoy this meeting and your stay in Kananaskis.

THE AUTHOR

JOHN BENSON is the Director of the Alberta Forest Service's (AFS) Forest Protection Branch and is located at the Provincial Forest Fire Centre in Edmonton, Alberta. He received a B.Sc. degree in forestry from the University of New Brunswick (1959). John joined the AFS upon graduation and worked in the Grande Prairie Forest as Divisional Forester (1959-61) and as Assistant Superintendent/Fire Control Officer (1961-67). He was the Senior Fire Control Instructor at the Forest Technology School in Hinton from 1967 to 1969 before becoming Forest Superintendent of the Edson Forest (1969-77) and the Bow-Crow Forest (1977-81). John worked as the Director of the AFS Forest Land Use Branch in Edmonton (1981-85) before assuming his present position.

HIGHLIGHTS OF COUNCIL BUSINESS MEETING

Permanent Secretary-Treasurer
Interior West Fire Council:

Jack W. Peters
Division of Forestry
Montana Department of State Lands
Missoula, Montana

The council business meeting was called to order by the secretary-treasurer acting as chairman at 8:45 a.m. on October 25, 1988.

1. The secretary-treasurer read the minutes of the 1987 joint annual business meeting of the Intermountain and Rocky Mountain Fire councils held in Jackson, Wyoming. The 1987 minutes were approved as read by the membership.

2. The secretary-treasurer presented the treasurer's report to the membership. It was moved, seconded, and approved by the members that the report be approved as presented. The following is the treasurer's report as presented to the members (in $U.S.):

Intermountain Fire Council Account	
Balance December 13, 1987	$12,113.31
Expenditures 1987-88	13,480.96
Income 1987-88	4,248.11
Balance October 15, 1988	$ 2,880.46

Interior West Fire Council Account	
Balance February 3, 1988	$7,000.00
Expenditures 1987-88	389.15
Income 1987-88	1,838.00
Balance October 15, 1988	$8,448.85

Richard Sandman IFC Memorial	
Balance January 22, 1987	$1,802.32
Expenditures 1987-88	0.00
Interest income 1987-88	110.49
Balance January 22, 1988	$1,912.81

The present Intermountain Fire Council (IFC) regular account will be closed out and the account balance will be placed in a higher interest bearing account. The account had been maintained for the past year to handle income received by the old Intermountain Fire Council. A minimum balance will also be maintained in the Interior West Fire Council account to handle annual expenses while the major balance of the account will also be placed in a higher interest bearing account.

3. Unfinished Business:

   a. The secretary-treasurer presented a short report on investment alternatives for the Richard Sandman IFC Memorial account and the IWFC operating account. The Richard Sandman IFC Memorial funds are now placed in a 1-year certificate. The intent is to earn increased interest from the council accounts by placing them in secure short- and long-term investment options such as Certificate of Deposits (CDs). This will help increase the number and/or the amount of the present student scholarships that are presented by the council annually.

   b. A working committee had been appointed at the 1987 joint IFC-Rocky Mountain Fire Council meeting to present a revised constitution and bylaws to the 1988 membership but were unable to meet prior to the 1988 meeting. The secretary-treasurer had prepared a revised proposal, and with the working committee's approval, it was presented to the members of the council. The membership felt that additional time was needed for review of the proposed constitution and bylaws and that approval should be deferred until the 1989 annual meeting. The chairman requested that comments be sent to the secretary-treasurer by January 1, 1989. These comments will be reviewed and incorporated where appropriate.

The membership at the 1988 annual business meeting approved, in the interim, the following arrangement of membership and host rotation for future council meetings. This concept has also been incorporated into the attached revision of the constitution and bylaws. The council membership will be by zones with the following rotation:

Zone	Member organizations	Order of rotation	Year
A[1]	Alberta, Northwest Territories	4	1992
B	Idaho, Montana	2	1990
C	Colorado, Utah, Wyoming	3	1991
D	Kansas, Nebraska, North Dakota, South Dakota	1	1989

A new steering committee configuration for the Interior West Fire Council was selected by members of the existing steering committee during a special steering committee meeting and presented to the council membership for approval. Approval was received from the council members to establish the following steering committee configuration. This configuration has also been incorporated into the attached constitution and by-laws.

The number of steering committee members will be increased from 10 to 12 with committee members serving two-year terms. Six members will be replaced annually as their terms expire. The twelve (12) members will be representatives from the following governmental levels, agencies, or organizations of the United States and Canada:

State/provincial/territorial	3
Federal	3
Industry	2
Universities/colleges	2
Research	2
Total	12

Selection of the new steering committee members will be done annually in the following manner: a) the hosts for the meeting to be held in one (1) year will select three (3) new steering committee members; and b) the hosts for the meeting to be held in two (2) years will select the final three (3) new members for the steering committee.

Selection of the new committee members by the upcoming hosts should be made prior to the annual business meeting so that their names may be announced at the current year's meeting.

The following members will serve on the steering committee for the term listed:

Name	Representing	Term
Robert L. Baker	Industry	1987-88[2]
John F. Chapman	Federal	1987-88[2]
Michael J. Jenkins	Universities/colleges	1987-88[2]
John E. Benson	State/provincial/territorial	1987-88[2]
Edward E. Mathews	State/provincial/territorial	1987-88[3]
Ronald J. Zeleny	State/provincial/territorial	1988-89[4]
Lou Gildemeister	Private industry	1988-89[4]
Darrell E. Smith	Federal	1988-89[4]
Martin E. Alexander	Research	1988-89[4]
Penny Morgan	Universities/colleges	1988-89[4]
Needs appointment	State/provincial/territorial	1989-90[5]
Needs appointment	Federal	1989-90[5]

The following members need to be appointed to the steering committee as soon as possible by the upcoming hosts:

Industry	1
Federal	2
Universities/colleges	1
Research	1
State/provincial/territorial	1
Total	6

---

[1] The province of Manitoba and Saskatchewan have indicated an interest in becoming members of the council. If either province requests membership and receives approval, they would probably become part of Zone A.

[2] Members' terms have expired and need replacement. New members will need to be selected and serve for 1989-90.

[3] Members' current term has expired but has agreed to stay on an additional year to balance out replacement cycle.

[4] Members will continue to serve the second year of their two-year term.

[5] Additional members added to the steering committee that require appointment.

Hosts for the 1989 Interior West Fire Council meeting is Zone D consisting of the states of Kansas, Nebraska, South Dakota, and North Dakota. Zone D hosts will select three (3) new steering committee members as soon as possible and inform the council secretary.

Hosts for the 1990 Interior West Fire Council meeting is Zone B consisting of the states of Idaho and Montana. Zone B hosts will also select three (3) new steering committee members as soon as possible and inform the council secretary.

The two zone hosts should coordinate their selection process to fill the vacant steering committee membership.

c. Any other unfinished business. There was no additional unfinished business presented.

4. New Business

a. Establishment of guidelines for awarding scholarships. The establishment of scholarship guidelines was referred to the steering committee. Dr. Penny Morgan, University of Idaho, will work on a proposal for the guidelines and coordinate the 1989 student scholarship selection with the hosts of the 1989 annual meeting. The secretary-treasurer provided a copy of a proposed IWFC scholarship student application form for the committee's review.

b. Establishment of guidelines for recognition of outstanding individual or organization in fire management. Referred to the IWFC steering committee to address.

c. Individual agency reports were not requested from the various agencies and organizations represented at the annual business meeting in the interest of staying on schedule. Copies of the written reports received are attached for your information.

d. The Forestry Conservation Communications Association (FCCA) report was also not presented as no one was in attendance at the IWFC business meeting that had attended the 1988 FCCA annual meeting.

e. Appointment of a resolutions committee. A committee was appointed to draft resolutions for presentation and approval by the membership. The following resolutions were approved.

f. Any other new business. There being no further new business the annual meeting was adjourned until the next annual or special meeting is held.

RESOLUTIONS

Reimbursement of Fire Fighting Resources

The United States and Canada have developed and adopted several mutual aid cooperative fire suppression agreements to best utilize fire protection equipment and personnel to meet emergency needs. Legislative authority does exist to provide the necessary authority for United States fire agencies to reimburse foreign fire suppression agencies for services rendered but this will expire at the end of this year.

In light of the 1987 and 1988 fire suppression demands, the Interior West Fire Council urges the United States government to renew the necessary reimbursement authority for the utilization of fire fighting resources regardless of jurisdiction, and requests that the United States, departments of Agriculture and Interior, and the Chief of the USDA Forest Service, actively pursue reauthorization on a permanent basis.

It was moved and seconded that the Fire Council support this resolution. Membership voting was unanimously in favor of the motion for support of the resolution as drafted.

A copy of this resolution will be submitted to the Western Forest Fire Committee at the annual meeting of the Western Forestry and Conservation Association in December, 1988 at Seattle, Washington, by representative member(s) of the Interior West Fire Council.

Thanks to Our Canadian Hosts

The Interior West Fire Council members would like to thank our Canadian hosts for the excellent job they have done in hosting the first official annual meeting of the combined fire councils. Their thoroughness in planning, preparation, and follow through has resulted in an educational, enjoyable, and well attended meeting. We thank you.

It was moved and seconded that the Fire Council approve this resolution. Membership voting was unanimously in favor of the motion thanking our Canadian hosts.

INTERIOR WEST FIRE COUNCIL CONSTITUTION

(Adopted October 25, 1988)

ARTICLE I

Name:

Section 1. The name of the organization shall be the "Interior West Fire Council" for the states of Colorado, Idaho, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah, Wyoming, for the province of Alberta, and for the Northwest Territories.

ARTICLE II

Purpose:

Section 1. The purpose of the Interior West Fire Council will be to provide a group representing private, state, provincial, territorial, and federal forestry agencies, forest industries, universities and other related activities which will advise and stimulate research groups on matters of fire research and equipment development, and to promote new and improved methods of fire prevention and control, and beneficial use of fire.

Section 2. Specifically the council will:

a. Assist in developing, adapting and utilizing modern fire management measures appropriate to the maintenance of a desirable environment and sustained yield of renewable resources through exchange of information.

b. Preview current wildland fire problems and recommend needed research and pilot projects.

c. Support the development and field testing of equipment and techniques which will aid fire management, prevention, control, and the beneficial use of fire.

d. Collect, prepare, and disseminate technical guides and general information resulting from projects of the Interior West Fire Council or its member organizations.

e. Promote strong commitments to interagency cooperation and coordination at national and international levels.

f. The purposes of the Interior West Fire Council shall be limited to charitable, educational, and scientific purposes within the meaning of Section 501 (c) (3) of the U.S. Internal Revenue Code.

g. No substantial part of the activities of this council shall be the carrying on of propaganda or otherwise attempting to influence the legislation, and the council shall not participate in or intervene in (including the publishing or distribution of statements) any political campaign on behalf of any candidate for public office.

h. Notwithstanding any other provisions of these articles, the council shall not carry on any other activities not permitted to be carried on by:

1. An organization exempt from federal income tax under Section 501 (c) (3) of the U.S. Internal Revenue Code of 1954 (or the corresponding provisions of any future United States Internal Revenue Law).

2. An organization, contributions to which are deductible under Section 170 (c) (2) of the U.S. Internal Revenue Code of 1954 (or the corresponding provision of any future United States Internal Revenue Law).

ARTICLE III

Membership:

Section 1. The council members shall include representatives of private forest industries, state forestry agencies, provincial and territorial fire agencies, timber protective associations, Bureau of Land Management, U.S. National Park Service, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. National Weather Service, Forestry Canada, universities and colleges, and any other organizations or individuals concerned with or interested in the creation of improved fire prevention and control, and beneficial use of fire through research and development activities. All representatives of the foregoing groups will automatically become members of the fire council by indicating their desire for membership.

Section 2. No part of the net earnings of the Interior West Fire Council shall insure to the benefit of, or be distributable to its members, officers or other private persons except that the council shall be authorized and empowered to pay reasonable compensation for services rendered or goods received.

ARTICLE IV

Officers:

Section 1. The officers of the council shall be a chairperson and vice-chairperson, each to serve for a one year term. A permanent secretary-treasurer will be maintained by the state of Montana for the council. It is the intent of the organization to rotate the chairperson and vice-chairperson positions between state foresters, the Director of the Forest Protection Branch of the Alberta Forest Service, or the Director of Fire Operations in the Department of Renewable Resources of the Northwest Territories, in the Interior West in the following sequence: Alberta, Colorado, Idaho, Kansas, Montana, Northwest Territories, Nebraska, North Dakota, South Dakota, Utah, and Wyoming. The vice-chairperson shall become chairperson the following calendar year.

Section 2. Officers Duties:

a. The chairperson shall be the chief executive officer; he or she shall preside at all meetings; he or she shall see that all orders and resolutions voted on by the membership are acted upon and put into effect.

b. The vice-chairperson, in the absence of the chairperson, shall preform the duties and exercise the powers of the chairperson.

c. The secretary-treasurer shall keep minutes for council meetings; shall have charge of all records and finances; shall mail minutes of each meeting to regular members and others in attendance who so request; and shall perform such other duties as may be assigned by the chairperson. In the event both the chairperson and vice-chairperson are absent from a meeting, the secretary-treasurer shall exercise the powers of the chairperson.

ARTICLE V

Method of Operation:

Section 1. A steering committee shall be appointed by the chairperson and will consist of twelve (12) members: three (3) from state, provincial, or territorial fire agencies, three (3) from federal fire agencies, three (3) from private industry, two (2) from a college or university, and one (1) from research.

Section 2. Terms shall be so that six (6) members are appointed each year. The term on the steering committee shall be for two (2) years. Steering committee members may serve no more than two consecutive terms. The chairperson and vice-chairman are *ex officio* members of the steering committee. The administrative head of any group whose principal and permanent purpose is fires, wildland, or allied fire control or research, may be asked to become an *ex officio* member of the steering committee.

Section 3. The chairperson, with the advice and guidance of the steering committee, may appoint *ad hoc* committees as needed.

ARTICLE VI

Meetings:

Section 1. Meetings may be called by the chairperson or secretary-treasurer, when necessary, to carry out the responsibilities of the council. Normally, a minimum of one (1) meeting shall be held each calendar year, and wherever desirable and necessary, the council will hold two meetings per year.

ARTICLE VII

Responsibilities:

Section 1. The Interior West Fire Council shall be responsible for the following activities:

1. To promote the dissemination of information on research programs and results.

2. To outline the problems in fire management which need research and to consult with fire research organizations on priorities of attack.

3. To survey research facilities that may assist in research and development activities in the Interior West.

4. To develop means of speeding the application of research and development results to problems in fire prevention, control and beneficial use of fire.

5. To encourage private, state, provincial, territorial, and federal participation in cooperative research and development programs.

6. To promote and stimulate research which is of a high level of scientific and professional effort.

7. To assist in informing the general public of the importance of fire research and development activities in the protection and management of private, state, provincial, territorial, and federal natural resources.

ARTICLE VIII

Resolutions:

Section 1. Resolutions approved by the Interior West Fire Council must pass by a two-thirds (2/3) majority vote of the quorum present.

ARTICLE IX

Constitutional Amendments:

Section 1. Amendments to this constitution may be proposed in writing by any member. Proposed amendments shall be mailed, along with the author's name and address, to the full membership at least 30 days prior to the next annual or special meeting.

Section 2. Proposed amendments shall be voted upon at the next annual or special meeting following mailing of the proposal to the membership.

Section 3. Proposed amendments may be rewritten or withdrawn during the meeting.

Section 4. Ratification of amendments shall be by a two-thirds (2/3) majority of the quorum present at the meeting.

Section 5. Ratified amendments shall be mailed to all members and will become effective the next January 1.

ARTICLE X

Dissolution:

Section 1. Written intent to dissolve the Interior West Fire Council will be by a two-thirds (2/3)majority of the quorum present at the next meeting.

Section 2. Dissolution of this constitution and the Interior West Fire Council will be by a two-thirds (2/3) majority of the quorum present at the next meeting.

Section 3. Upon dissolution of the Interior West Fire Council, the officers shall, after paying or making provisions for the payment of all of the liabilities of the council, dispose of all of the remaining assets of the council exclusively for the purposes of the council in such a manner, or to such organization(s) organized and operated exclusively for charitable, educational, or scientific purposes which shall at the time qualify as exempt organization(s) under Section 501 (c) (3) of the U.S. Internal Revenue Code of 1954 (or the corresponding provisions of any future United States Internal Revenue law), as the officers shall determine. Any such assets not so disposed of shall be disposed of by the Circuit Court of the county in which the principal office of the council secretary-treasurer is then located, exclusively for such purposes or to such organization(s) as said court shall determine, which are organized and operated exclusively for such purposes.

INTERIOR WEST FIRE COUNCIL BY-LAWS

A. *Membership*:

Section 1. Members will maintain active standing by attendance at not less than one council meeting out of each three. Thirty voting members' (members in active standing) representing at least ten (10) agency members shall constitute a quorum. In the absence of a quorum, a letter ballot shall be used.

B. *Meetings*:

Section 1. Written notices of meetings shall be mailed at least 30 days prior to such meetings. The chairperson shall assume responsibility to keep the council informed on matters it should handle. The council will evaluate the matter and decide on appropriate action.

Section 2. The council chairperson shall annually appoint a program chairperson. This chairperson shall be a member from a participating organization in the host state or province for that year's meeting. The program chairperson may enlist additional assistance from IWFC members to serve on the program committee.

Section 3. The regular annual meeting of the Interior West Fire Council will be held during the month of October or November each year at a place selected by the chairperson.

Section 4. Meetings shall be conducted in accordance with Robert's Rules of Order.

C. *Policy Statements*:

Section 1. Include as a part of each annual business meeting an update on current operations by participating agencies, and an update on current work being carried on in the equipment development centers and fire research labs.

Section 2. A report form a regional representative at the annual Forestry Conservation Communications Association (FCCA) is to be requested for each annual meeting.

Section 3. The council will attempt to award scholarships annually based on the approved scholarship guidelines.

Section 4. The council will attempt to recognize annually an individual or organization that has made an outstanding and dedicated contribution of time and effort in the advancement and support of fire management practices and principals.

D. *By-Laws Amendments*:

Section 1. By-laws may be amended only during annual or special meetings of the council.

Section 2. Proposed amendments may be initiated and voted upon at the same meeting.

Section 3. Two-thirds (2/3) majority of the quorum present shall be required to amend by-laws. Changes shall become effective upon their passage.

Section 4. By-laws changes shall be distributed to all members together with the minutes of the meeting.

THE AUTHOR

JACK PETERS, the permanent secretary-treasurer of the Interior West Fire Council, is the supervisor of the Fire Suppression Section in the Montana Department of State Lands Division of Forestry office, which is headquartered in Missoula, Montana. He received an Associate Arts degree from Sandhills Community College, Southern Pines, North Carolina (1968) and a B.Sc. degree in forestry from the University of Montana (1971). Jack spent 3 years with the U.S. Army at the Deserret Test Center at Fort Douglas, Utah (1962-64). He worked seasonally in Waterton-Glacier International Peace Park for 4 years as a fire guard and park ranger. Jack has been employed as a forester for the State of Montana's Department of State Lands since 1972 and has held his present position as Fire Suppression Supervisor and State Fire Coordinator since 1976. In 1985, he assumed the role of permanent secretary-treasurer of the Intermountain Fire Council.

WESTERN FORESTRY AND CONSERVATION ASSOCIATION (WF & CA)/WESTERN FIRE COMMITTEE

1988 WF & CA Western Fire Committee Chairman:

Kenneth C. Roegner
U.S. Department of Interior, Bureau of Land Management
Oregon State Office
Portland, Oregon

It is indeed a pleasure to attend the first annual meeting and workshop of the Interior West Fire Council. I bring to you a warm welcome from the officers of the Western Fire Committee and those of the wildland fire community who participate in the Western Fire Committee of the Western Forestry and Conservation Association.

The Western Fire Committee is looking for many good fire persons as opposed to "a few good men." Participation is the key word. We are seeking your participation in committee planning, program development, solving of issues, and resolutions. The committee is a way for each of us to expand our understanding of fire and resource, technical, and policy issues.

What is the Western Fire Committee? It is a committee under the Western Forestry and Conservation Association (see The Story of the Western Forestry and Conservation Association) and one of five such association committees that are involved with forest resources (forest pests, reforestation, forest land use, and stand management). The committee is an extension of four western North American fire councils: the Interior West Fire Council, Southwest Fire Council (Arizona and New Mexico), California-Nevada-Hawaii Fire Council, and Northwest Fire Council (Oregon, Washington, British Columbia, Yukon, Alaska). Through this extension of fire councils, the Western Fire Committee and Western Forestry Conservation Association, we can expand our effectiveness on fire-related issues.

We in the Western Fire Committee want to build up a trust among the fire councils, a trust that will build understanding of and effectiveness on fire-related issues. It can happen if we agree to participate and give it a try. With participation there will be an opportunity for improvement and effectiveness. Without it there will be a struggle and a chance of failure.

You were represented at the 1987 annual meeting of the Western Fire Committee by members of this council who took a very active role in the gathering of information and some of the planning for the 1988 affair. We urge more of you to follow the lead of Ken Egerman, Tim Murphy, Lou Gildermeister, Mick Koppang, John Crumb, and others in your council.

At the 1987 meeting of the Western Fire Council there were nine resolutions submitted to the Western Fire Committee for consideration by the four fire councils. Of these nine resolutions, seven were adopted as submitted or combined with other similar resolutions. Only two were not adopted because of their very local significance. The net result was six Western Fire Committee resolutions that were all adopted by the Western Forestry and Conservation Association at the 78th Annual Western Forestry Conference. The Interior West Fire Council's resolution dealt with reimbursement of foreign governments for fire-fighting support. Federal legislation to solve that problem for 1988 was drafted and passed. We feel that the letters from the Western Forestry and Conservation Association to various elected officials had a part in getting this legislation passed. More work is needed for 1989, and the U.S. Congress is aware of the issue, but we might need to remind them.

Similar action was taken on the other resolutions adopted by the Western Forestry and Conservation Association. Letters of recognition and appreciation were received from legislators and government officials, both in the United States and Canada.

What are the issues and policies we need to address through resolutions at this first annual meeting and workshop of the Interior West Fire Council? Is current fire management policy something that needs support or review?

The next meeting of the Western Forestry and Conservation Association and Western Fire Committee is to be held December 4-7, 1988, in Seattle, Washington. The fire managers meeting begins on Sunday afternoon, December 4. We are going to discuss fire issues and council resolutions. This meeting is an opportunity for you to bring these issues out in the open for discussion and action. At the meeting, John Langrell and Dave Nelson of the Western Fire Committee will handle fire-related issues and resolutions, respectively. At this year's annual meeting of the Western Forestry and Conservation Association, the Western Fire Committee will have a business meeting, a joint technical session with other committees, and a fire-oriented technical session. In addition to these sessions, participants will be able to attend general sessions of the Western Forestry and Conservation Association and other technical committee sessions if a topic or speaker attracts their fancy and meets their needs. Gordie Schmidt of the USDA Forest Service, Pacific Northwest Region, is the program chairman for the 1988 Western Fire Committee, and he has done an outstanding job in putting together the fire-oriented technical session. It is in line with the theme of the 79th Annual Western Forestry Conference, which is "Informed decisions: are you using the latest information and technology?"

The 1989 meeting of the Western Fire Committee will be held at Sacramento, California, and the 1990 meeting will be in Spokane, Washington. We are looking for a vice-chairperson for the 1989 meeting who will become chairperson for the Spokane meeting. John Langrell and I will be here for the entire week. Please visit with us and consider attending the 1988 Western Fire Committee meeting.

The Story of the Western Forestry and Conservation Association

The Western Forestry and Conservation Association is a unique organization which, since 1909, has worked to advance forest resources management, protection, and utilization. The Association unites private and public forestry and conservation interests of the western United States and western Canada in a joint effort. Today, having a distinguished history of achievement, the Association works with renewed purpose to secure the forestry future of western North America through cooperative effort. Under the banner "One Forest Under Two Flags," Canadians and Americans of the west join hands to accomplish the following:

- promote the practice of forestry and the development of forest conservation on all forest land in the western United States and western Canada;
- provide an open forum for exchanging and disseminating forestry and conservation information; and
- bring about cooperation among federal, state, provincial, and private forest agencies.

The association is supported by forest landowners, forest industries, governments, universities, and individuals who wish to further these objectives.

The Western Forestry Conferences. The most popular activity of the Western Forestry and Conservation Association is the annual Western Forestry Conference. One of the largest forestry meetings in the west each year, the conference is held in early December in one of several major western cities on a rotating basis. The conference, consisting of general and technical sessions, attracts a broad range of people with an interest in forestry. General sessions include all attendees and feature a keynote speaker as well as discussion. Attendees also break up into technical sessions and listen to speakers of expertise in particular fields of interest. A wide range of forestry experts for public and private industry, as well as universities and other institutions, come together at the conference to exchange knowledge and ideas on current issues and problems. Each attendee can participate in discussions and policy formulations and can then apply the latest forest technology to forest practices and policies.

Forestry leaders in the western states and provinces recognize the Western Forestry Conference as an important medium. There, foresters have opportunities to broaden viewpoints, make contacts, share knowledge, and increase professional stature. Young professionals can become acquainted with leaders of industry and public agencies and also listen to and participate in discussions of regional and national forest policies. The opportunity to freely exchange ideas with other foresters on problems confronted daily is just one of the conference's many benefits. Conference programs are planned by a committee of western forest resource leaders. Resolutions written and approved by various committees are used to crystallize western forestry concerns for needed action and to modernize the association's policy statement—a charter for progress in practical forest conservation.

Policies. The association's staff actively promotes policies in coordination with other forestry associations. The staff represents the association before meetings of congressional committees, service clubs, chambers of commerce, professional groups, forestry schools, and forest industries through periodic bulletins, correspondence, and personal contacts. Policies of the association are updated annually to reflect current forestry viewpoints and are derived from membership expression. Membership input has been influential in policy determination of several national resource organizations. Various issues in which association policies have been effective include land use, forest protection, pesticides, forest taxation, and several areas of forest research.

Committees. One outstanding cooperative enterprise of the Western Forestry and Conservation Association is the division of committees into five major fields: forest fire, forest pests, reforestation, forest land use, and stand management. Each committee holds its annual meeting during technical sessions at the Western Forestry Conference. The committees also study pressing problems in each field and recommend action programs to the association.

Publications. Conference proceedings, which consist of abstracts from speakers at the Western Forestry Conference, are mailed to all members. Complimentary copies are sent to university and other selected libraries. Newsletters describing the association's activities are mailed three times each year to all members.

The work of the Western Forestry and Conservation Association and the results of its efforts accrue to the benefit of all members, whether they be forest landowners, tree farmers, or forest industry members. Through the association, federal, state, provincial, and industrial forest managers find a common meeting ground and forum for resolving mutual problems. The association correlates the thinking and efforts of all branches of forest ownership and management for common advancement. The association, which pioneered cooperative forestry enterprise, has shown the continuing worth of cooperative problem-solving. The approach offers hope for solutions to future problems.

THE AUTHOR

KEN ROEGNER, the 1988 chairperson of the Western Forestry and Conservation Association's Western Fire Committee, is a forester (Fire Management) with the U.S. Department of Interior in the Bureau of Land Management's (BLM) Oregon State Office in Portland, Oregon. He received a B.Sc. degree in forest engineering from Oregon State University (1952). Ken started working for the BLM in 1955, with assignments in Eugene, Oregon; Redding, California; Medford, Oregon; and Portland, Oregon. In his current position he is responsible for fire prevention, trespassing, training, budgeting, contracts, and agreements. Ken is past secretary, resolutions chairperson, vice-chairperson, and chairperson of the Northwest Fire Council and currently serves as a steering committee member.

FORESTRY CANADA HOSTED LUNCHEON

Master of Ceremonies:

A. David Kiil
Regional Director General
Northern Forestry Centre
Forestry Canada
Edmonton, Alberta

INTRODUCTORY REMARKS

Ladies and gentlemen! It is a pleasure for me to welcome you, on behalf of Forestry Canada, to the First Annual Meeting and Workshop of the Interior West Fire Council in Kananaskis Country. This meeting is yet another manifestation of the excellent cooperation and goodwill between fire researchers and managers from both sides of the 49th parallel.

I have no doubt that your decision last year to form the Interior West Fire Council, by consolidating the Intermountain and Rocky Mountain Fire Councils, will prove to be a positive one and will further strengthen the traditions and friendships established during the preceding decades. People like Art Brackebusch, Dick Sandman, Ken Eggerman, and Gareth Moon, to name but a few key players, deserve a lot of credit for their dedication and contributions on behalf of the council.

A couple of weeks ago, Marty Alexander was kind enough to remind me that I attended my first meeting of the Intermountain Forest Fire Research Council at Boise, Idaho, in 1963—just 25 years ago! As a matter of fact, fire researchers from Alberta and elsewhere always looked forward to the annual meeting of the Intermountain Fire Research Council and considered it as *the* fire meeting to attend. We all recognized and appreciated the benefits of our involvement in the council's business, and we finally started to reciprocate by hosting the 1978 and 1983 meetings in Edmonton and Banff, respectively.

My trip report of the 1963 meeting indicates that the sessions focused on the critical fire period, fire prevention, fire hazard reduction, fire behavior evaluation, initial attack on fires, and reinforcement action on fires. Some of the same topics are covered in this year's program under the general theme of "The art and science of fire management." At the same time, it is gratifying to see on the agenda topics such as the wildland and urban interface, forestry industry involvement in fire protection and use, wildland firefighter safety, interagency cooperation, production rates of fire suppression crews, ecological fire management in national parks, application of computer-based information systems, and determination of fire protection priorities within a values-at-risk framework—a good indication that fire researchers and managers continue to search for and apply new knowledge and technologies to reduce fire costs and losses to acceptable levels.

The council is also rather unique in the mix of its membership. Aside from its international flavor, it draws its members from both operational and research agencies involved in fire management, thereby ensuring strong emphasis on problem identification and definition and, ultimately, the timely application of the research product for the benefit of all. This places the council in a strong position to achieve its objectives on behalf of the fire management community in the Interior West region.

Finally, I would like to recognize the major contribution of the Program Committee under the cochairmanship of Marty Alexander of Forestry Canada and Gordon Bisgrove of the Alberta Forest Service. They have developed an excellent and well-organized program that has attracted about 250 participants. Please join me in extending to them a vote of thanks for an outstanding job!

The Northern Forestry Centre of Forestry Canada is pleased to participate in this, the first annual meeting of the newly formed Interior West Fire Council and wishes you every success in the future.

INTRODUCTION OF GUEST SPEAKER

Ladies and gentlemen, it is a distinct privilege for me to introduce our guest speaker, Mr. Herbert W. Beall, who will speak on the topic of "Fire research in Canada's federal forestry service—the formative years".

Herb started his fire research career in 1928—exactly 60 years ago—and he will tell us about his personal recollections covering a distinguished career spanning a period of some 35 years.

Herb, along with Jim Wright, pioneered forest fire research in Canada. They have served, and continue to serve, as inspiration to past and current generations of Canadian fire researchers.

I believe that the seeds for the current cooperation between Canadian and U.S. fire researchers were planted in the mid-1940s when Herb visited Harry Gisbourne at Priest River in Idaho. Over time, Kananaskis and Priest River have become identified with important developments in fire research on both sides of the 49th parallel. It is, therefore, very fitting that Herb is here today to share his recollections of these formative years.

On a personal note, I joined the federal forestry service in 1960 as a young fire research officer. In 1961, following the establishment of a federal department of forestry, Herb Beall was appointed as director of the newly formed department's administration branch. This meant that I did not have an opportunity to work with Herb the fire researcher, but his philosophy and accomplishments provided strong guidance during my formative years in fire research.

Herb's accomplishments are too numerous to mention. Suffice it to say that he was instrumental in developing the foundation for today's Canadian Forest Fire Danger Rating System used nationally as well as in several other countries. He also provided the basis for the establishment of fire protection standards across Canada, including burned-area objectives and the concept of the relationship between elapsed time from the start of a fire to initial control action and final fire size.

Ladies and gentlemen, please join me in welcoming our guest speaker, Mr. Herb Beall, fire researcher emeritus.

THE AUTHOR

DAVE KIIL is the Regional Director General for the Forestry Canada Northwest Region, which is headquartered at the Northern Forestry Centre in Edmonton, Alberta. He received his B.Sc. degree in forestry from the University of Toronto (1960) and his M.Sc. degree in forestry from the University of Montana (1967). Except for a 10-month stint in 1973 with the federal Department of Indian and Northern Affairs in Ottawa as the Forest Protection Coordinator, Dave has spent his entire professional career with the Canadian Forestry Service (CFS). He was initially located in the fire research section in Ottawa prior to transferring to Calgary, Alberta, in 1962 and then relocating to Edmonton in 1967, where he served as a fire research officer, fire research coordinator, and research scientist until 1973. From 1973 to 1975, he served as the technical specialist for fire research with CFS-HQ in Ottawa. Dave returned to Edmonton in 1975 as the fire research project leader and was later (1977) promoted to the Program Director level. He assumed his present position in 1981.

LUNCHEON ADDRESS

FIRE RESEARCH IN CANADA'S FEDERAL FORESTRY SERVICE—THE FORMATIVE YEARS

Herbert W. Beall
Canadian Forestry Service (retired)
Ottawa, Ontario

ABSTRACT

The year 1925, in which J.G. Wright formulated his concept of a fire-hazard rating system, is perhaps the most significant date in the evolution of forest-fire research in Canada. But a decade earlier the first (though transitory) attempt in this country to quantify the relationship between weather and forest flammability was made here in Alberta. Wright's early work was centered at Petawawa, Ontario, but fire research spread progressively, reaching Kananaskis in 1939 where important contributions to the system were made. From the outset Wright maintained close, cordial and fruitful contacts with H.T. Gisborne and others in the United States. His work remains the foundation of today's Canadian Forest Fire Danger Rating System. In the 1930s funds for fire research were slim; necessity was the mother of invention for improvising much equipment. The researcher, too, was usually responsible for technology transfer; i.e., persuading the head of the fire control service to adopt the system, and then training his often skeptical ranger staff in how to use it. World War II saw drastic curtailment of fire research on both sides of the border. At Kananaskis, zest and sometimes amusement or danger were added to the job by an internment camp for POWs. Some personal anecdotes related to these and other aspects of the early days of fire research are recounted.

ADDRESS

Mr. Chairman, distinguished guests, ladies and gentleman: May I say what a pleasant surprise it was to receive from Marty Alexander an invitation to this conference, to meet old and new friends, and to say a few words by way of reminiscence. Marty was too polite to put the time limit quite so bluntly, but the implication is pretty clear. Indeed, one runs a real risk in inviting us old-timers to say anything at all. Once we get the bit between our teeth it may be an awful job to get us stopped, especially if, as I suspect may be the case here, nobody else has been around long enough to challenge any mental lapses on our part, wives always excepted. Anyway, I'll try to avoid these pitfalls.

Mary and I are especially pleased to be back in Kananaskis Country, almost exactly 50 years since we first arrived to set up a fire research program on the East Slopes. We were assigned a trim little log cabin at the mouth of Lusk Creek, just a stone's throw across the river from here. Coming from the stodgy East, we found the scenery marvelous, the air crisp, and the wildlife both interesting to us and interested in us. In fact, I soon had to arm Mary with my trusty .32 rimfire rifle, to scare away the bears who insisted on visiting her while I was away on my daily rounds of weather and fuel moisture observations.

Later that year, firearms took on a potentially more sinister use. Canada became involved in war in Europe, and in no time at all a barbed-wire enclosure was erected at what is now the lower end of Barrier Lake. This was used to intern suspected Nazis and enemy aliens, guarded by World War 1 veterans who were already getting a bit long in the tooth, but delighted to have rifles in their hands again.

All of this caused a good deal of excitement and even some hint of danger at the Kananaskis Forest Experiment Station. The internees were garbed in blue, with a large red circle on the back. I used to wear a red windbreaker on the crisp autumn days, which half a mile or so up the mountain, might be mistaken for an escaped prisoner's outfit.

This idea hadn't occurred to me until one afternoon, up the Lusk Creek Road, while cheerfully whirling my sling psychrometer and weighing my fuel trays, I heard the rattle of gunfire in the valley far below. This I took to be musketry practice by the guards, until something whizzed past my ear and ricocheted off a rock ahead. I must have set some sort of record for getting down that hill, and I was careful thereafter to wear something less likely to make me look like an escapee. But the thought has occurred to me that if the honest old veteran who wrinkled me out of my field site that day had had a clearer eye, or steadier hand, or perhaps hadn't spent so much time in the canteen the night before, a promising career in fire research might have been nipped in the bud, and you, my friends, might have been spared listening to this tale!

Going back a bit in history, Alberta has from the outset played an important role in the evolution of forest fire research in Canada. I'll give you one example, which also shows how coincidence often takes a hand in these matters. On my arrival here in 1939, I found that a rosy-cheeked undergraduate from the University of Alberta had been assigned as my assistant. He had accepted the job on the advice of his physics professor, who turned out to be L.H. Nichols whom I had met some years before when he initiated fuel moisture studies in Quebec. Thus was Jack Turner launched on a very distinguished career in forest meteorology. I'm sure he was known personally or by reputation to many of you here.

To go back still further, 1925 is commonly accepted as the beginning of forest fire research in Canada, for reasons that I'll revert to in a minute. As early as 1916, E.H. Finlayson introduced here in Alberta what seems to have been the first attempt in this country to quantify forest flammability. It was a crude system that didn't last long after "Fin" went to Ottawa and became head of what is now Forestry Canada. But his work was contemporary with that of such western American pioneers as Bevere Show and J.A. Larsen, and all three seem to have had much in common. Conceivably they may have gotten together to exchange ideas, anticipating our gathering today by three-quarters of a century.

Returning now to 1925, early in that year a young civil engineer in the Dominion Forest Service named Jim Wright arranged for the Canadian Meteorological Service to provide weather equipment and special fire-weather forecasts for the Dominion Forest Service (DFS). In a memo to his director, written the day before Christmas the same year, (which should be required reading for Canadian fire researchers), Wright reported progress on the Meteorological Service cooperative program, and went on to outline his ideas of how fuel moisture, and hence flammability, might be measured by correlation with rainfall, atmospheric humidity, temperature, and wind. This was the germ of what came to be known as the Wright System. He persuaded the director to let him follow this up with field research, thus laying the foundation for today's Canadian Forest Fire Danger Rating System.

It should be added that the director was Ernest H. Finlayson, who is perhaps not always given sufficient credit for his introduction and early support of forest fire research.

From the beginning, Wright corresponded with fellow workers in the United States—notably Harry T. Gisborne at Priest River, Idaho, and Paul W. Stickel in New England. Through Gisborne he obtained several duff hygrometers, designed to measure moisture in the surface litter. These were calibrated at the Forest Products Laboratory in Madison, and installing them at Petawawa in 1928 was my first job with the DFS. They made an important, if temporary, contribution to the development of fuel moisture instrumentation.

It may be worthwhile to briefly compare the methods used by Gisborne, Stickel, and Wright in working towards a common objective—that is, the measurement of forest flammability and fire danger. All three found the relationship between fire behavior and fuel moisture in various fuel types by observing fire characteristics at known moisture levels. Each defined the degree of fire hazard in the terms low, medium, and high, which are household words today.

Now for the differences. Gisborne measured fuel moisture daily at each recording station by weighing sticks whose dry weight was known. This system was adopted at many stations in British Columbia and at some in Alberta. Stickel, having once found the relationship between the weather elements and fuel moisture, needed only weather readings for daily application. Wright used the same principle as Stickel but took into account the previous day's fuel moisture as an extra variable.

Again, Gisborne devised a simple, cardboard, slide-rule type meter to integrate the elements of fire danger. Stickel used alignment charts (then very popular in the U.S. Forest Service) to get the hazard index from his weather observations. Wright relied on plain, old-fashioned tables for the same purpose.

With regards to the methods of determining correlations, the Americans seemed to prefer the rather rigid regression equations of the day, which we Canadians found not flexible enough to handle the complex, joint functional relationships between weather and fuel moisture that kept turning up in our studies. So we opted for the graphic methods of correlation analysis espoused by Mordecai Ezekiel in the U.S. and by Prof. T.W. Dwight in Canada. These freehand curves were frowned upon by the statistical purists, but they seemed to work, besides allowing scope for imagination where data were scarce.

A feature of the Wright System, shared in some degree with Stickel's, was its adaptability to predicting hazard and danger indexes by using forecasts of weather in the tables instead of actual values. At any rate, all these systems had their advocates and all produced useful results.

Among Jim Wright's many successful inventions, not all of which were concerned with danger rating, was the Wright evaporimeter. This device integrated the drying effects of weather by daily measuring the loss of water from a tin can exposed under a sort of umbrella. Many of these were put into service but they were eventually abandoned in favor of direct weather readings.

Undoubtedly the most useless fire-weather instrument the CFS produced was a horrible invention of mine called the Beall dew gauge. It was supposed to collect dew on polished steel rods suspended over a rain gauge. The prototype, constructed at vast public expense, had only one defect—it never collected one drop of dew. To add insult to injury, a bright young technician, Albert Potvin, made a dew gauge by clamping a one-foot-square sheet of window pane at a angle over a measuring glass, and it worked beautifully!

I first had the privilege of being associated with Jim Wright at the Petawawa Forest Experiment Station in Ontario. His early fire-hazard tables were designed for important forest types there as well as for open-field grass. By 1935 we began spreading east, and in 1939, as already noted, a fire research program was started here at Kananaskis. By this time it was evident that weather and fuel moisture relationships determined at one well-chosen site could be adapted to represent a wide range of fuel, topographic, and geographic conditions. An important objective of the Kananaskis studies was to tie into the system the effects of temperature inversion and low night humidity specific to mountainous country.

War brought forest fire research to a virtual halt on both sides of the border. Wright was seconded to the Eastern Arctic Administration, from which, alas, he never returned to the CFS.

The spring of 1941 found me in the Royal Canadian Air Force, learning the secrets of radar at a base in southwest England. One morning I was summoned to the orderly room and told to report forthwith to a very senior officer in the Air Ministry at London. To us, the Air Ministry was like the Pentagon to the United States Army. Obviously some tremendous and probably catastrophic event had occurred in which I, a lowly flying officer, was the culprit. My sins flashed before me during the ensuing train trip to London, and I think I was more scared than at any other time during my four years overseas. What crime had I committed? Would I be clapped in irons, thrown into the Tower of London, hanged, drawn and quartered, or what?

When I got to the Air Ministry, which then included the British weather office, I was soon put at ease. It seemed that the German Air Force was reported to have devised a cunning scheme to set the grain fields of Britain afire. Showers of phosphorus-coated paper strips, soaked in water, were to be dropped by Luftwaffe raids over the countryside. When they dried it was expected that these would ignite spontaneously and burn up the crops. Apparently, at a conference on coping with this treat, someone recalled that the Canadians had a system for measuring the flammability of forests and grass lands and thought that maybe this would help. I gathered that a hasty call was made to Ottawa and the director of the Forest Service. Sandy Cameron advised them to track down a fellow named Beall who was supposed to be somewhere in England in an Air Force uniform.

Heaving a sigh of relief, I got a copy of our grass-fire hazard tables for the British Forestry Commission and suggested that they give it a try, as an aid to organizing presuppression and control action. Then I went back to the radar school, rejoicing in the belief that I'd had a hand in saving the beleaguered Brits from starvation.

A few months later, when on leave, I visited an acquaintance in the Forestry Commission who was "in the know" about the Luftwaffe's plans. I was delighted to learn that the scheme had been a complete flop, much like the Japanese incendiary balloons on the west coast of this continent a short time later. The phosphorus strips had stubbornly refused to ignite. All, that is, except a few that were picked up by farmers, stuffed in their jacket pockets as curios, and forgotten until the jackets were hung over the fire to dry.

So our fire hazard tables, through no fault of their own, didn't really contribute much to saving Britain's food supplies, though it might be fair to give them honorable mention. Today, by the way, may well be the first time this formerly classified episode has been referred to in public.

My first post-war job, as newly appointed head of the federal forest fire research unit, was to sound out the provincial fire managers' priorities as to what research we should tackle. One was to simplify the structure of our fire danger tables which I could now see had grown excessively cumbersome. We had fallen into the trap not uncommon among enthusiastic researchers, of tacking interesting but nonessential bits onto a basically good thing, until what should have been the means was becoming the end in itself. With this and other projects under way, in 1946 I had the long-awaited pleasure of calling on Harry Gisborne at Priest River.

Although Jim Wright in particular had been in close contact by correspondence with colleagues across the border, personal visits were few and far between. My only previous exposure to fire control organizations in the States had been a one-day trip to Glacier Park, Montana, in 1940, where I learned a tremendous amount. This time I was able to spend four days in Idaho and Montana. I discovered that Gisborne and I shared many problems, especially those of post-war restaffing and reactivating research programs. He had recently been joined by Jack Barrows, who was away on a new aerial bombing project, and whom I didn't meet until many years later. But I surely did envy "Gis" and his student assistant, Colleen McCarthy, their laboratory equipment, especially their thermostatically controlled electric drying ovens. All our field station experience had been with two-hole kerosene cook stoves and homemade ovens for drying fuel samples, which needed constant manual control.

Another of Gisborn's technological marvels was an enormous "meteorology tower," rising 47.5 metres through a magnificent stand of timber, with fully instrumented platforms at intervals on the way up. Ascent, however, was by a fairly frail-looking outside ladder that didn't even have hoops on the back to give one some sense of security. Gis asked me if I'd like to climb up. Being no lover of heights, this was the last thing I wanted to do, but there was something in his tone that implied a sort of challenge, so I said, "Of course, nothing I'd like better." He tactfully went into his office, leaving me alone. I got to the top and down again all right, duly reported to Gis the wonders I'd seen, and felt that Canada's honor had been upheld.

Harry Gisborne's death, three years later, was a sad blow to his colleagues, to his profession, and to his friends everywhere.

Before drawing these recollections to a close, I should point out that in Jim Wright's day we were all expected to be general practitioners of the business, not just specialized researchers. He taught us three important rules. First, never miss an opportunity to promote interest in fire-danger rating by potential users. Second, provide what is now called the "technology transfer" necessary to get a danger-rating network set up and operating smoothly. And third, offer a follow-up checking service to ensure that accurate readings and records are maintained.

In the first category, I recall one rather amusing episode concerning a provincial deputy minister of forests, a very good friend of mine, who felt quite honestly (and stubbornly) that there was no future for the Wright System in his territory. He visited Petawawa while I was still in the business. I took him out to the site, then still in operation, where the fuel moisture measurements had been made years before that provided the tracer index in the Wright Tables representing the moisture content of surface litter. This was done by weighing a cloth-lined wire tray containing match splints of known dry weight. I explained that if we weighed the tray, the percent moisture of the splints should agree with the tracer index plotted on the chart at the station headquarters, which was calculated from noon weather readings. We weighed the tray, calculated the moisture content, and returned to headquarters where the tracer index for the day had just been worked out. Lo and behold, it agreed precisely with our figure! My friend was mightily impressed, and not long after his fire control service adopted the Wright System.

Although I stuck my neck out a bit that time I wasn't really too worried, having checked in advance that all the equipment was in order. We also relied on the remarkable property of the tracer index to compensate for errors, because it started with the previous day's index and registered only the change. This feature is virtually infallible after a few day's dry weather, and fortunately the good Lord had laid this on for my friend's conversion. Sometimes the end justifies the means!

The second of Jim's rules, technology transfer, produced some of the most difficult as well as rewarding incidents. Our weather stations were often set up at lookout towers and pioneer homesteads, where the potential observers had more practical than academic skills. Sometimes they looked as though they wanted to climb the nearest tree on first beholding the formidable array of instruments and documents they would have to master. But patience and forbearance on both sides always paid off. And great was the pride of the fire warden who used to have to rely on his own judgment when telling settlers it was too dry to burn slash. It was his word against theirs. Now he could point to the chart on the wall and say, "Sorry, Joe, the chart says you can't burn." To this there was no rebuttal.

As to Wright's third rule, providing follow-up service to check the accuracy of work being done, here again Alberta came to the rescue. A fire- danger rating system was organized in the Canadian national parks just about the time that the internment camp at Kananaskis was set up. Some of the internees, who had obviously been caught in the initial war-time panic, were conscientious, well-educated citizens, whose curiosity may have prompted them to look in at some pro-Nazi meeting. A couple of these were pressed into service checking the weekly weather records and fire-danger charts from all the western parks. This resulted in what must have been the most thoroughly vetted forest weather and danger-rating system in the country.

To sum up, on looking over these notes I'm appalled to find how often the word "I" is used: "I" did this; "I" said that. My only excuse is that it is difficult to avoid the personal pronoun in what is largely based on personal recollection.

But I do want to make it abundantly clear that Jim Wright was definitely, in every respect, the senior partner in our team. Wright provided the inspiration; Beall contributed to the perspiration. Moreover, Wright's genius and leadership were by no means confined to fire danger studies or other kinds of fire research. After a long and distinguished career that included research, administration, education, and municipal government, Dr. James Goldwin Wright died just two years ago at the age of 93.

I'd also like to pay tribute to the able and dedicated fire researchers and supporters who have carried on from the pioneer stage to this day. It would be invidious to single out individuals for mention and would take too long to list all who deserve it. The present Canadian Forest Fire Danger Rating System bears eloquent witness to their accomplishments. (Frankly, it's gone way beyond my depth!)

Finally, I am aware that the same sort of ability and dedication have characterized fire research workers in the post-Gisborne era in the United States. It has been my privilege to know a good many of them, and it is gratifying to see how the spirit of friendliness and cooperation has been maintained across the international boundary. This may well have begun in the days of Snow, Larsen, and Finlayson and is certainly well exemplified in the Interior West Fire Council and gatherings such as this.

Ladies and gentlemen, you are to be congratulated on setting so high a standard of international cooperation and good will. It is a pattern that others would do well to follow.

Good luck, God bless, and thank you.

THE AUTHOR

HERB BEALL was born in Ottawa in 1908 and received his education at Lisgar Collegiate. He attended Queens University and the University of Toronto where he graduated with a B.Sc.F. degree in 1932. Starting in 1928, Herb Beall worked as a summer student on fire research projects with J.G. Wright at the Petawawa Forest Experiment Station. Following university graduation, H.W. Beall joined the Forest Service of the Department of the Interior as an assistant to Wright in forest fire research. In 1941 he joined the Royal Canadian Air Force, serving with radar units in the United Kingdom and Middle East. He left the RCAF in 1945 with the rank of Squadron Leader and returned to the Dominion Forest Service as chief of the Forest Protection Division. In 1952 he was made Chief of the Forestry Operations Division, Department of Northern affairs and Natural Resources, responsible for the administration of cost-shared agreements with the provinces under the Canada Forestry Act. In 1961 he was appointed director, Administration Branch, Department of Forestry, and in 1965 was named Special Advisor to the Deputy Minister, a position he held until his retirement form the Canadian Forestry Service (CFS) in 1969. Mr. Beall was a part-time consultant to the CFS, Canadian International Development Research Centre from 1969 to 1979. Herbert Beall and his wife Mary live in Ottawa. They have two children, Elma and James, and five grandchildren.

PRESENTATIONS TO HERBERT W. BEALL

A. Dave Kiil
Northern Forestry Centre
Forestry Canada
Edmonton, Alberta

Thank you, Herb, for an excellent presentation. You were able to skillfully combine recollections of career highlights with personal philosophy. Your observations about the need to promote application of research products is as valid now as it was 50-60 years ago. Today's presentation has reinforced the widely held belief by Forestry Canada fire researchers that you have left us with a strong legacy of excellence and commitment that will be both a challenge and opportunity for future generations. In recognition of your contribution here today as well as your career accomplishments, it is a pleasure for me to present to you, on behalf of Forestry Canada, a framed print depicting a familiar view of Kananaskis Forest Experiment Station shortly after World War II.

Canadian Forestry Service Fire Research Belt Buckle

Dennis E. Dubé
Forest Science Directorate
Forestry Canada
Ottawa, Ontario

About a year or so ago, Forestry Canada fire researchers decided we should never be caught with our pants down, so we struck a limited edition belt buckle[1], 250 in total, each individually numbered with the following inscriptions. On the front of the buckle is "Canadian Forestry Service Fire Research." On the back is the following:

> Since 1925, Canada's federal forestry service has been conducting research on the physical behavior, ecological role, and economic impact of forest fires for the general improvement of fire management in Canada for the benefit of all Canadians.

Herb, on behalf of all Forestry Canada fire researchers, past and present, I would like to present to you belt buckle Number 1 for the tremendous contribution you have made to fire research in Canada.

Wood Panel-mounted Duff Hygrometer

Martin E. Alexander
Northern Forestry Centre
Forestry Canada
Edmonton, Alberta

Herb, on behalf of the Interior West Fire Council, I would like to present to you this duff hygrometer (circa 1928). The inscription on the plaque reads as follows:

Presented to:
HERBERT W. BEALL
in appreciation for his address to the
Canadian Forestry Service Hosted Luncheon
First Interior West Fire Council Annual
Meeting & Workshop
Kananaskis Village, Alberta
October 25, 1988

We've very much enjoyed having you and your wife Mary attend our first annual meeting and workshop here in Kananaskis Country. Take care.

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[1] The fire research belt buckle project was coordinated by R.S. McAlpine of the Northern Forestry Centre (NoFC) in Edmonton, Alberta. M.E. Alexander of NoFC penned the inscription appearing on the back of the buckle.

KEYNOTE ADDRESS

THE ART AND SCIENCE OF FIRE MANAGEMENT

Peter J. Murphy
Faculty of Agriculture and Forestry
University of Alberta
Edmonton, Alberta

ABSTRACT

The setting of the first annual meeting and workshop of the Interior West Fire Council in the historic Kananaskis Valley provides an opportunity to draw on local lessons from the past to guide and caution us during our rapid transition to the future. Six stages or hierarchies are identified and equated to those of Maslow in the evolution of our present system of forest fire management. Observations, insights, and admonitions for the future are presented.

INTRODUCTION

"The art and science of fire management" is a well-chosen theme that speaks well for the perceptivity of the organizers, Marty Alexander and Gordon Bisgrove, and their program team. I will approach it in two ways—first through an historic timeline, which is important both for perspective and because it is part of our heritage; and secondly through a review to outline a hierarchy of events suggested by this history, and to draw some inferences from it. The Kananaskis Valley will be the focal area, because it provides a neat local analog of major trends and events. The historical review also illustrates how actions towards fire began largely as an art, with science emerging as a major force more recently and with the need for both art and science increasingly recognized.

This presentation is also intended as a tribute to the spirit of practitioners in the fire management field from the earliest days up to and including the present.

HISTORICAL TIMELINE

This country was essentially the domain of the Stoney Indians, who took over from the Blackfoot in the early 1800s. Although the Stoney were largely resident on the prairies and in the major valleys, this valley was used for spiritual purposes as well as for hunting. There is reason to believe that the Stoney practiced the art of meadow burning in several locations in this area to maintain pasture for horses and provide open areas in which to camp.

Captain John Palliser traveled up the Kananaskis Valley in the fall of 1856 as part of his survey of Rupert's Land for the Imperial Government and to search for possible railway passes. It was difficult traveling, and his diary noted evidence of recent fires, confirmed in fire history studies to have occurred earlier that year. The major fire year in this valley was 1890, an event that was the culmination of an approximately 3-year period of extensive fires along the Rocky Mountain chain. At that time there was no organized fire control.

When the Dominion of Canada acquired Rupert's Land from the Hudson's Bay Company in 1869, just 2 years after Confederation, the lands were incorporated as the Northwest Territories and managed by the federal Department of the Interior. It was a huge land with little access and few residents. Completion of the Canadian Pacific Railway in 1885 established a transcontinental link and marked the beginning of increased travel to and through the region. When the railway arrived in Calgary in 1883 it prompted a building boom that spurred the rapid development of a sawmilling industry. Timber along the Bow and Kananaskis rivers was seen as a valuable resource, and logging and milling began in 1884. Logs were driven by river to mills located on the Bow River near the Kananaskis and particularly to the large Eau Claire mill in Calgary.

Early Department of the Interior staff inspecting this region were continually struck by the evidence of fires in the forests, and their reports advocated providing means for preventing and controlling them; however, little was done in light of the vast areas involved, the small human population on which to draw, and limited financial resources of the federal government. The major catalyst was the development of irrigation on the southern prairies, which added considerably to the value and saleability of railway lands. Because the water supplies were drawn from the east slopes of the Rockies, fire control to protect the watersheds was judged essential. Various representations led to the establishment of the Rocky Mountains Forest Reserve in 1911 through an act of Parliament, an area which included the Kananaskis Valley. The Dominion Forest Service was charged with responsibility for its protection and management (Huth 1980; Murphy 1985).

A major initial problem was access into the forested areas because there were virtually no roads and only a few rudimentary trails. As the principal mode of transportation was the horse, early efforts focused on building trails to enable staff to get around. The major objective was control of forest fires, so building of lookouts and construction of caches, stop-over cabins, ranger stations, and phone lines were also parts of the job.

As access improved, campers, fishermen, and hunters quickly followed. Because these travelers were deemed to be potential fire-starters, patrols were designed to maintain a high Forest Service profile with them. As the number of users increased, the Forest Service developed campgrounds in order to congregate campers into fire-safe areas, thereby initiating recreation management, but from a fire prevention standpoint. Similarly, range management was also begun as a fire prevention measure through encouragement of livestock onto the Forest Reserve to consume the tall grasses, then seen primarily as a fire hazard.

But fires did occur. We are well aware of the big blow-up of 1910 in Montana, Idaho, and eastern Washington. We also had some 1910 burn in the Highwood Valley immediately to the south, but our major problems were to occur about a decade later. In 1919 drought conditions led to extensive burns south, east, and north of the Kananaskis Valley. More seriously, during the last week in May a series of fires through eastern Alberta and central Saskatchewan destroyed the village of Lac La Biche and affected a total area that may have been as great as 3.2 million ha, the actual extent of which we are still studying. A fire burned in the Kananaskis Valley in 1920 running 28 km north from Lower Kananaskis Lake to near the mouth of Galatea Creek. This fire was neither fought nor reported because of its remoteness at that time. It is interesting to note that the Royal Canadian Mounted Police were involved on another 1920 fire in the Spray River Valley immediately to the west of, at that time, part of the national park. The RCMP had been actively involved in prairie fire fighting throughout the west and were still being called upon to assist during emergencies in the national park areas.

In 1930 the federal government turned over the natural resources within the three prairie provinces of Alberta, Saskatchewan, and Manitoba to their respective provincial governments. At that point the Alberta Forest Service was formed to take over the management responsibility here, while the federal government focused its resources on developing programs in forest research.

The next fire of interest in this valley occurred in 1933 when the Pocaterra fire burned 580 ha near Lower Kananaskis Lake. This fire was successfully fought, but the fire report indicated that it took 4 days to get men from Calgary to the fire—a reflection of the improving, but still primitive access. A major fire year occurred in 1936. A wildfire burned northward up the Elk Valley in British Columbia over a period of several weeks, alternately making major runs and lying dormant in response to weather conditions. The Alberta Forest Service sent in a fire crew by horse up the Highwood on July 23 to try to hold the fire at Fording Pass on the Continental Divide. The fireline was built and held, but during a blow up that night, the fire spotted east into Alberta, starting fires well below the crew, so they pulled back to make a stand along Cataract Creek and the Highwood River. The fire made several major runs during that week under gale force winds. Meanwhile, another fire crew was sent in on foot south from Lower Kananaskis Lake over Elk Pass to try to stop the fire at its head, well into British Columbia. The line was built and held except for one blow-up when the crew took shelter in a creek, later holding the fire again after its 3 km run. The adventurousness and determination of these crews is to be greatly admired.

In the meantime, a lightning-ignited fire had started high up on Galatea Creek to the north, burning out the head of that valley and working its way down towards its junction with the Kananaskis. The fire was undetected for several days because of the heavy smoke drift from the other fires to the south. When it was finally discovered a crew was sent in, but the fire blew up about the time the crew arrived. Taking shelter in the river, the men watched the fire burn over them and run down the Kananaskis Valley, cleaning off the side of Mount Kidd, the lower slopes of Mount Allan, and ending near Mount Lorette. Kananaskis Village and the Olympic facility of Nakiska on Mount Allan are located on this burn site.

Earlier in 1936 the federal government had consolidated its commitment to forest research in Alberta by establishing a forest research station on the lower Kananaskis. It was at this location that Herb Beall started work 2 years later on his pioneering studies leading to developing a scientific base in fire studies. The fire of 1936 also spurred road building activities by whatever means possible in order to improve access for fire control.

A unique federal-provincial agreement was signed in 1948 establishing the Eastern Rockies Forest Conservation Board to manage the Forest Reserve under joint federal-provincial administration. The agreement recognized the importance of the east slopes watershed to the major prairie rivers. A major federal grant led to greatly increased road building activity featuring a trunk road that ran through the major mountain valleys linking the Crowsnest Valley in the south to the Kananaskis Valley in the north and later through the northern part of the Forest Reserve to Nordegg. The road greatly facilitated recreational traffic, which enabled greatly increased numbers to savor the scenic qualities of the country and set the stage for the subsequent declaration of Kananaskis Country in 1978. That, in turn, led to paved highways and commercial recreational facilities of a very capital-intensive nature. So, while we have been gradually able to increase our fire control capability, we have created a new problem by placing costly structures in a flammable environment.

The last major fire of note occurred on the north side of Upper Kananaskis Lake in 1967. A lightning strike near the lake resulted in a fire that burned intensely through an old growth stand and ran up to the timberline and over a pass. This provided an opportunity for the Alberta Forest Service to test its new native fire crew training program by bringing in a "certified" crew from Wabasca in the flatlands of northern Alberta. The men were flown to Calgary in a DC3 and then brought to the Upper Lake at night where camp had been set up for them. Story has it that they were astonished in the morning when they came out of their tents to see this mountainous country standing on its edge, and marvelled at how such a land could be. They quickly adjusted, however, and proved their worth, soon bringing the fire under control.

EVOLVING HIERARCHY

This history suggests that in our evolutionary process we have passed through several eras in our development of a fire management system. These eras are not discrete but evolutionary with considerable overlap; however, they provide a useful basis for discussion.

Earliest efforts focused on *injunction and prevention* in the belief that fire problems could be eliminated by removing the causes (Fig. 1). These actions focused on legislation such as the 1832 ordinance of the Council of Assiniboia and subsequent ordinances of the Northwest Territories. Concurrent with these was an extensive program of prevention including posters, many of which were translated into native languages and languages of the European settlers. Activities included participation in the Calgary Stampede parade and exhibits at various local rodeos and fairs. In northern areas "fire ranging" was effected through canoe patrols and by working closely with native Indians who were encouraged to take a fire prevention pledge. Even the prototype roads contained fire prevention signs. There were two major forces that minimized these artful efforts, however, one was lightning with its pervasive influence and the second was extension of agricultural settlement into forested lands. Clearing trees for agricultural production was a gargantuan, heartbreaking task, and fire was seen as a simple means by which to facilitate the conversion process. As a result, the second era of *physical* attack on forest fires was eventually inaugurated. In 1911, H.R. MacMillan defined the problem in a statement that seems to have formed the basis for much of the subsequent activity of forest services:

> "The measures adopted to protect the forest from fire are now generally understood. They are the removal by education or legislation adequately enforced of the causes of fires, the organization of a patrol to find and extinguish such fires which will inevitably start, and the improvement and organization of the forested areas so as to render most efficient the efforts of fire fighters and to minimize the chance of any fires getting beyond control."

Physical attack focused on fighting fires with hand tools and developing the infrastructure to detect and facilitate access to fires.

The advent of *mechanical* devices increased the opportunities for successful attack. Arrival of the

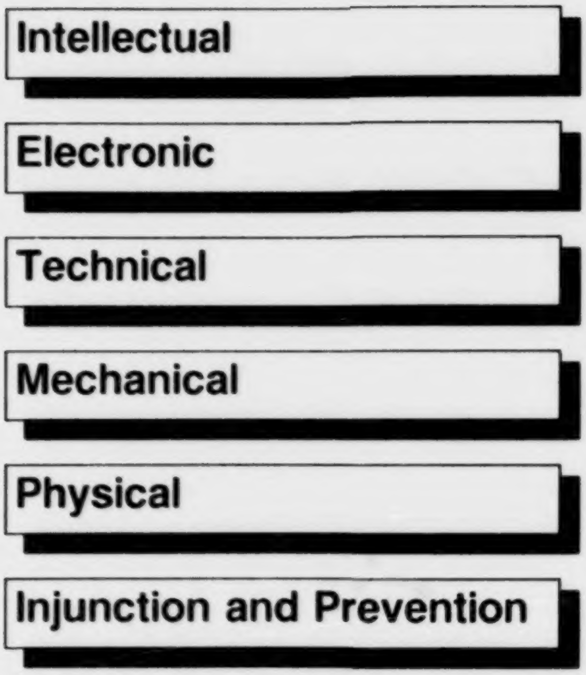


Figure 1. Hierarchy of needs in forest fire management.

power pump was widely heralded, even though the portability of some of the earlier models posed problems. Rangers of the day noted how fire crews would often scale back on their efforts when the sound of the pump was heard, in anticipation that water would do the job without the necessity of physical labor. Similarly, when the bulldozer came on the scene, similar psychological reactions occurred. This is evident today with aerial attack as well. It is important to note in this hierarchical arrangement, that effectiveness of the top category is dependent on maintaining strength in all of the underlying ones.

The *technical* era was launched with the early studies of Jim Wright, Herb Beall, and others who began the process of quantifying relationships between fire, weather, and other forces. Their tables have been widely used, refined, and adapted across Canada. The arrival of calculators and computers enabled us to make a quick transition to greatly enhanced data handling and calculations, and the more recent development of the portable computer has enabled us to carry these capabilities into the field. During this time, forest fire science had clearly established its importance and was the focus of major attention.

I suggest that we are now in an *intellectual* era, which recognizes the importance of both science and the art of its application. There is no question that we need science—as stated by William Shakespeare: "There is no darkness but ignorance." We need science and its products to enhance our abilities to understand and to act effectively; however, we equally require the application of human intellect to bring the various elements together and to apply science to the problems at hand.

We have, therefore, developed a hierarchy that might be seen as roughly analogous to the one described by Maslow (1970) concerning human development. His point was that survival was the first law in which food and shelter are paramount needs (Fig. 2). The subsequent requirements lead sequentially to creativity, a quality very much characteristic of this group. However, sustaining creativity

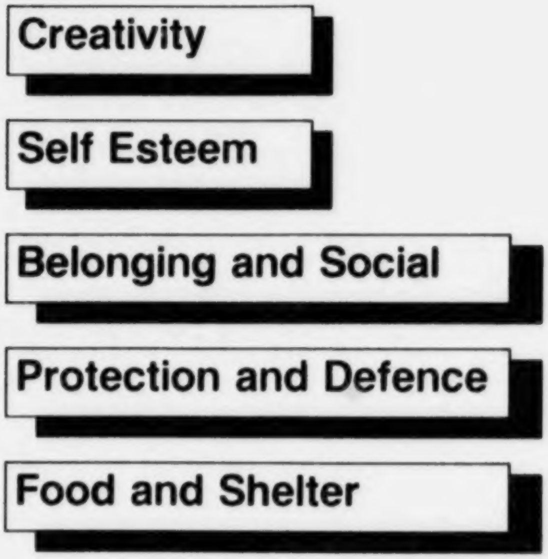


Figure 2. Maslow's hierarchy of human needs.

is entirely dependent on maintaining the base of the four more-fundamental concerns. In forest fire management our ability to apply our collective intellect to fire management problems is also dependent on maintaining capability and strength in the underpinning categories as well.

The complementarity of art and science in fire management is not a new thought—R.H. Luke stated it succinctly in 1962:

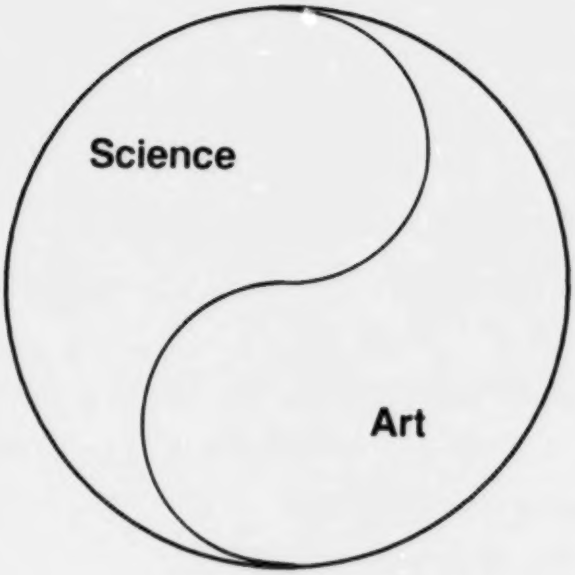
> "As the result of continuing research fire control has, in many of its aspects, become a science. It is difficult, however, to see how in the practical application of these scientific principles it can be anything other than an art."

This relationship is illustrated in Figure 3 in which art and science are depicted as complementary activities, both of which are required to form the whole. Harmonization of both will be increasingly important as we move into the future. As John Naisbitt stated in *Megatrends*: "Things aren't going to get better. They're going to get different."

In the Rocky Mountains Forest Reserve, age-class studies indicate that the fire cycle has been increased from around 30 years in 1909 to about 770 years in the 1970s. So, while we have many areas such as the Kananaskis Valley and the national parks in which some means, such as reintroduction of fire, will have to be considered for effecting the cycles of disturbance and renewal, we have introduced capital-intensive structures into that same environment which have become very much at risk from fire. On the other hand, we have other large investments in forest products industries that are indirectly at risk to fire through loss of allowable cut. This latter concern is of increasing importance as our timber supplies become more fully allocated. Pogo summed up our perplexity succinctly when he said, "The future just isn't what it used to be."

CONCLUSION

We must tap our human intellect to the fullest extent possible, developing our collective capabilities in science and art through training and education on the job and through technical and university programs. And, while we strive to develop and adapt new



Science is Technology

Art is people....through which technology is applied

Figure 3. Complementarity of art and science in forest fire management.

techniques through science, we must maintain our previously established capabilities, which form the basis of our present strengths.

The heartening aspect is that the human spirit has continually demonstrated its determination to prevail, overcome, and achieve, seeking to rise above itself both physically and intellectually, as demonstrated in so many ways. Regardless of where future science takes us, we must apply our collective art to utilize it properly and effectively for the benefit of the environment and the human race.

ACKNOWLEDGMENTS

This presentation was accompanied in its entirety with slides illustrating the historical changes and characteristics of the various eras described. These photographs were obtained from the following sources: Alberta Fish and Wildlife Division, Alberta Forest Service, Bow Valley Provincial Park, Canadian Parks Service, Forest Technology School in Hinton, Glenbow Museum and Archives, Peter Lougheed Provincial Park, Provincial Archives of Alberta, Whyte Museum of the Canadian Rockies, and Paul Woodard. Sincere thanks are extended to these sources for making them available—the voluntary sharing of these photographs is very much appreciated. The graphics were kindly prepared by Rick Blackwood of the Alberta Forest Service. This collective generosity is characteristic of the spirit that prevails among fire and resource management professionals. It is a spirit that has carried us a long way together and has created a great environment in which to work.

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TECHNICAL SESSION I:

FIRE MANAGEMENT PROBLEMS AND OPPORTUNITIES

FIRE MANAGEMENT PROBLEMS AND OPPORTUNITIES

OPENING REMARKS

Moderator:

Howard W. Gray
Slave Lake Forest
Alberta Forest Service
Slave Lake, Alberta

The topic of problems and opportunities is an excellent session to open a workshop on the art and science of fire management as it provides focus for the sessions to follow. During this session many of the factors influencing fire management problems and opportunities will be discussed. Such factors as the fire environment, fire management policies, organizational considerations, fire regimes, and even politics all play a role. Many of these influences work independently or through interaction to create significant problems or pose interesting opportunities. In reviewing the outlines for the papers prepared by the speakers in this session and reflecting on the session theme it became evident to me that we must focus on the opportunities. To most fire managers, problems are really just unchallenged opportunities. Problems to a pessimist remain problems; but to enlightened, aggressive, or optimistic fire managers they are opportunities.

The following are several examples of problem-opportunity relationships you will hear about this afternoon:

- How do we get people to take a greater role in solving the problem of mixing people and homes with flammable vegetation?
- How do we replicate natural fire in a safe manner while still achieving the overall needs for renewal of an ecosystem? Such a problem or challenge may well relate to this summer's Yellowstone National Park experience. I am certain this topic will receive a great deal of attention by fire managers.
- How is an acceptable balance achieved between the effort to ensure that a fiber resource can be utilized and the costs involved? Such a challenge is certainly a factor to be considered by the private sector.
- How do we create a safe approach to dealing with the nature of the job of fire fighting, with its inherent dangers?
- Where, when, how, and why should prescribed fire be used?

In the eight papers presented in this session you will hear about some problems, but mostly you will hear about opportunities. You will hear how these opportunities have been accepted as challenges to be met through the application of the art and science of fire management.

THE AUTHOR

HOWARD GRAY is the Forest Superintendent of the Slave Lake Forest, which is headquartered in the town of Slave Lake in central Alberta. Howard joined the Alberta Forest Service (AFS) in 1964 and worked up to a District Ranger in 1971-72. In 1972, he bacame a district protection officer with the Northwest Lands and Forest Service of the federal government in Inuvik, Northwest Territories and was later (1973) promoted to Chief Protection Officer in the Fort Smith Regional Fire Centre. Howard returned to the AFS in 1976 as Senior Officer for the Planning Section in the Forest Protection in Edmonton. In 1977, he returned to a field operational role as Forest Protection Officer of the Slave Lake Forest, a position he held until returning to the branch as the head of fire control operations from 1981-86 prior to assuming his present position.

THE WILDLAND-URBAN INTERFACE: A NATIONAL FIRE PROBLEM WITH LOCAL SOLUTIONS[1]

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ABSTRACT

Because of the natural and social amenities offered by suburban and rural living, more and more people are moving to wildland environments. The combination of people, homes, flammable vegetation, and dry weather conditions is increasing the annual losses from wildland fires and bringing new issues and problems to wildland fire managers. In the past 3 years, 350 000 wildland fires burning over 6 million ha have damaged or destroyed about 2500 structures, killed nearly 100 people, and injured over 8000 firefighters and citizens. The total of the suppression costs added to the property and natural resource damage exceed 20 billion dollars. If these kinds of statistics are to be reduced, people living in wildland-urban interface areas must take more responsibility for their own fire protection. In addition, new fire prevention programs must be developed and more emphasis placed on increasing cooperation between wildland and structural fire agencies. Although the problem of urban-wildland fire is a national (and for that matter an international) one, much of the problem must be solved at the local level in a partnership between the public, fire service, builders, planners, architects, and community leaders. To be effective in the 1990s, those involved in wildland fire management will be seeking new models that apply to settings from wilderness to wildland-urban interface. Whatever these models are, their effectiveness will depend greatly on the existence of good working relationships between the agencies, groups, and individuals involved.

INTRODUCTION

Because of the natural and social benefits offered by suburban and rural living, more and more people are moving to wildland environments (Davis and Marker 1987; Gale and Cortner 1987; Laughlin and Page 1987; Bailey 1988; Bradshaw 1988; Fischer and Arno 1988). The combination of people and flammable vegetation can make disastrous fire situations. The worldwide problem of protecting people and resources from wildland fires is becoming more complex each year. Wildland-urban fires, in particular, are forcing us to reexamine our fire suppression strategy, tactics, and organizations. These fires bring us face to face with the realities of conducting complex operations in full view of a concerned but frequently uninformed public. As wildland fires may continue for weeks or even months, suppression forces often face the need to provide structure protection for extended periods. Fire managers and incident commanders must divert wildland fire-fighting resources to protect lives and property, and thus much greater natural resource losses occur. The California and Oregon fires in September of 1987 are good examples of fires where officials were forced to accept major resource losses in order to provide adequate structure protection. This choice will not go away soon as resource agencies and incident commanders have little inclination to face the controversy that inevitably erupts when local citizens perceive that not all possible measures were taken to protect their homes.

Wildland-urban fires pose such a significant threat to the well-being of the people and natural resources of the interior west that we need to meet the challenges of interface fire protection by becoming programs must be developed. More emphasis must be placed on increasing the cooperation between wildland and structural fire agencies. And people living in the wildland-urban interface areas must take responsibility for some of their own fire protection.

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[1] This presentation was supplemented with two videotapes shown twice during the annual meeting and workshop entitled *Protecting Your Home Against Wildfire* (19 minutes) and *Wildfire '87: Decision Point for the Future* (22 minutes), which were both produced by the National Fire Protection Association, Boston, Massachusetts.

The issues raised by the presence of homes in wildland areas are complex and, as the Yellowstone fireshave shown, the dramatic quality of major fires in recreational or inhabited areas guarantees that the fires will quickly acquire a political dimension. All of this means that fire managers, often working with constrained or unpredictable budgets, will have to develop improved working relationships with other agencies, the media, local government, and the public to be able to accomplish their fire management responsibilities in the 1990s. Since 1985 the losses from wildfires have generated staggering statistics[2]. In just 4 years some 3000 structures have been damaged or destroyed, over 100 lives have been lost, and over 8000 firefighters and citizens have been injured. The suppression cost combined with the resource and property loss has been estimated to exceed 20 billion dollars. This figure represents over 350 000 fires that burned over in excess of 6 million ha.

Often the human dimension is forgotten when considering wildfires. We have no way of estimating the emotional impact on people who lost family, friends, or personal possessions. How do you place a monetary value on family heirlooms or the emotional impact of a family life shattered by death or the terror of fires, or emotional trauma from the doomsday atmosphere created by the smoke pall hanging over communities for days, weeks, or even months?

THE LOCAL SOLUTIONS

Homes in the interface do not have to burn, and we do not have to continue to sacrifice our natural resources to protect them. People can live fire-safe in the wildlands. We can build fire-resistant structures, landscape to reduce fire hazards, and modify wildland fuels to reduce fire intensity. We can prevent many fires from starting.

At the national level, many organizations are more than willing to assist once they understand the problems. We are finding architects, insurance rating groups, the structural fire community, and the national media all willing to work with us.

The national and state levels can coordinate and facilitate awareness and cooperation, but that won't stop wildfires. The people at local levels make the difference and ultimately will meet the challenge of protecting both people and natural resources from the ravages of wildfire.

The challenge is to develop and implement fire loss reduction programs that meet the local needs and actively involve the people you are protecting. Take advantage of the interest created by the recent fires to enlist public support. Be willing to reach out and recruit help from the entire community. Many of the people that can help you in this effort only need to be asked.

Develop outreach programs that will help create community support for efforts and provide opportunities for citizen involvement. Focus on the human dimension, examining human perceptions of fire protection issues and the social, economic, and institutional facts that affect human behavior and response to fires. Grass roots involvement and leadership is a must in this effort and cannot be stressed enough. Strive for a full partnership with the citizens you protect. This is easier said than done, but it is critical to program success. Unlike so many problems today that go beyond the capability of the individual citizen, this is an issue where each individual can make a difference.

Gaining support from the community may also require that you be willing to look at some protection issues from different viewpoints. In Oregon earlier this year, a local homeowners group wanted to develop a community volunteer fire crew of 30 individuals. The local fire agencies said they could not support such efforts because of existing regulations. This is the type of community concern that fire managers must see as an opportunity rather than a burden. The expansion of interface populations is changing the political and social values in these areas. Successful fire programs must be sensitive to these changes.

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[2] 1985-88 fire statistics and records compiled at the Boise Interagency Fire Center, Boise, Idaho.

FRAMEWORK FOR LOCAL COOPERATION

As the focus of interface fire protection, many local fire departments and wildland agencies find themselves struggling to overcome the barriers between them. The following list of ideas and guidelines provides a rough framework for starting your interagency work:

1. Remember that one way or another we are all involved in interagency work. Because fires do not respect political boundaries, sooner or later we will deal with our counterparts in other agencies. We can either plan for it and make it work or try to improvise joint actions when emergencies force the issue.

2. Get to know your counterpart in other agencies. Meet with individuals in local government, homeowners, and business groups to listen and discuss fire protection issues.

3. Whatever you do, keep it simple. Work in areas where the greatest consensus about problems and solutions exists. Involve the people you protect and listen to their concerns and comments.

4. Once you've had some success, you'll begin to get the attention of people who are happy with the status quo. Listen to these people. There may be unresolved problems between agencies that have created a pessimistic climate for interagency proposals. Work with the people that see a need and then let events conspire to bring down barriers and draw other people into the process. Inevitably there will be some conflicts and political in-fighting but, as time goes on and programs begin to work, things will smooth out.

5. In your own organization, try to get people both at one level above you and one level below involved in this interagency process. Encourage the people you're working with in other agencies to do the same as this can serve as a good tool for spreading the word informally.

6. Constantly remind people that they do not have to solve all the problems that exist between departments or agencies to create a successful interagency process.

7. Remember that you do not have to give up your organizational priorities or procedures to be able to cooperate in fire prevention, presuppression, and suppression activities with other agencies.

Here are six major steps to building effective interagency cooperation (after Swinford and Tokle 1988):

Step 1: Involve others and obtain a commitment to work together.
Step 2: Examine your problems.
Step 3: Set your goals and objectives.
Step 4: Develop programs and policies.
Step 5: Approve and implement the plan.
Step 6: Evaluate and revise the program as needed.

CONCLUSIONS

In summary, there is much to do. We can build fire-resistant structures, landscape to reduce fire hazards, and modify wildland fuels to reduce fire intensity. We can build new partnerships with other government agencies and with groups and individuals throughout our communities. Organizational procedures and priorities do not have to be compromised to cooperate in the wildland-urban interface. Working together we can prevent many fires from starting and, when they do start, by working together we can dramatically reduce the losses. At times it may be difficult to work together—but the alternative is answering to an angry public after a disastrous fire about why our agencies did not work together during the fire. If we do not push ourselves to break down the artificial barriers between agencies, then in the end we are gambling with the lives and property of those we have pledged to protect.

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KEEPING THE FLAME: FIRE MANAGEMENT IN THE CANADIAN PARKS SERVICE

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Ottawa, Ontario

ABSTRACT

In Canada's national parks, ecological integrity cannot be maintained solely through protection. Active management is required to ensure that long-term processes such as fire continue their natural role. In the park areas, the mean annual natural burn area likely exceeded 1000 km². Recently, fire control has reduced the burn area by more than 90% in southern parks. In northern boreal parks, fire control efforts have likely not significantly decreased fire activity. The Canadian Parks Service (CPS) is entering into fire management with three parks currently conducting planned ignition fires and a further 10 parks actively planning for fire use. An external expert assessment and practical experience have identified several problems. These include the reticence of management plans to fully acknowledge fire as an ecosystem-level process that requires proactive management. Furthermore, the hesitation of individual parks to share specialized fire command staff and other limited resources can jeopardize field-level applications. The CPS is committed to solving these issues and to maintaining fire-dependent biotic communities in a natural environment.

INTRODUCTION

> *Only recently have we become keepers of the wild, but for all our existence as a species we have been, and will continue to be, keepers of the flame.*
>
> Pyne (1985)

The scientific and management complexity required to conserve natural ecosystems has increased many fold in the last century. We can recognize four phases of ecosystem management in national parks (Eidsvik 1985). Earliest came *preservation*, where conservation was possible through simple designation of park boundaries. Later, as tourism, poaching, logging, and other pressures increased, parks emphasized *protection*, which could be characterized by attempts to protect natural features from change. These changes included not only those caused by human use, but also long-term processes such as predation, forest insects and diseases, ungulate grazing, and fire. Increasing ecological understanding has led to *management*, where parks recognize that protecting ecosystems from change processes is not possible or desirable. Canadian Parks Service (CPS) policy (Parks Canada 1979a) requires that "national parks will be protected and *managed* [our emphasis] with minimal interference to natural processes to ensure the perpetuation of naturally evolving land and water environments and their associated species."

To manage, one needs to know what the components of the natural ecosystem are and how they interrelate. Hence, the CPS has developed a natural resource management process (Parks Canada 1979b) requiring ecological land classification, description, and analysis. This information should provide managers with the necessary tools to meet the critical challenge of moving from reactive protection to proactive resource management. This is a bold philosophical step, for it requires managers to explicitly define standards of ecosystem and "naturalness," to forecast the results of various courses of action, and to conscientiously choose a strategy. During this decision process, it will likely become apparent that parks are not islands of wilderness. Ecosystem processes such as acid rain do not respect park boundaries. This will lead to what Eidsvik (1985) terms *integrated management*, where conservation of ecosystems is achieved through continual cooperation between parks and neighboring land agencies.

In most national parks in Canada (Fig. 1) there is perhaps no more pervasive ecosystem process than fire. Thus, as parks make the transition from protection to management, the role of fire has provided a focus of continual attention. For not only is fire a natural process, but in northern forests it often triggers an explosive release of energy that, once begun, is completely beyond human control. In this paper we will present a brief history of fire in the CPS, describe current initiatives to enter the management period, and forecast prospects for the future. We will provide a personal "on-the-line" superintendent's view of fire in a busy park.

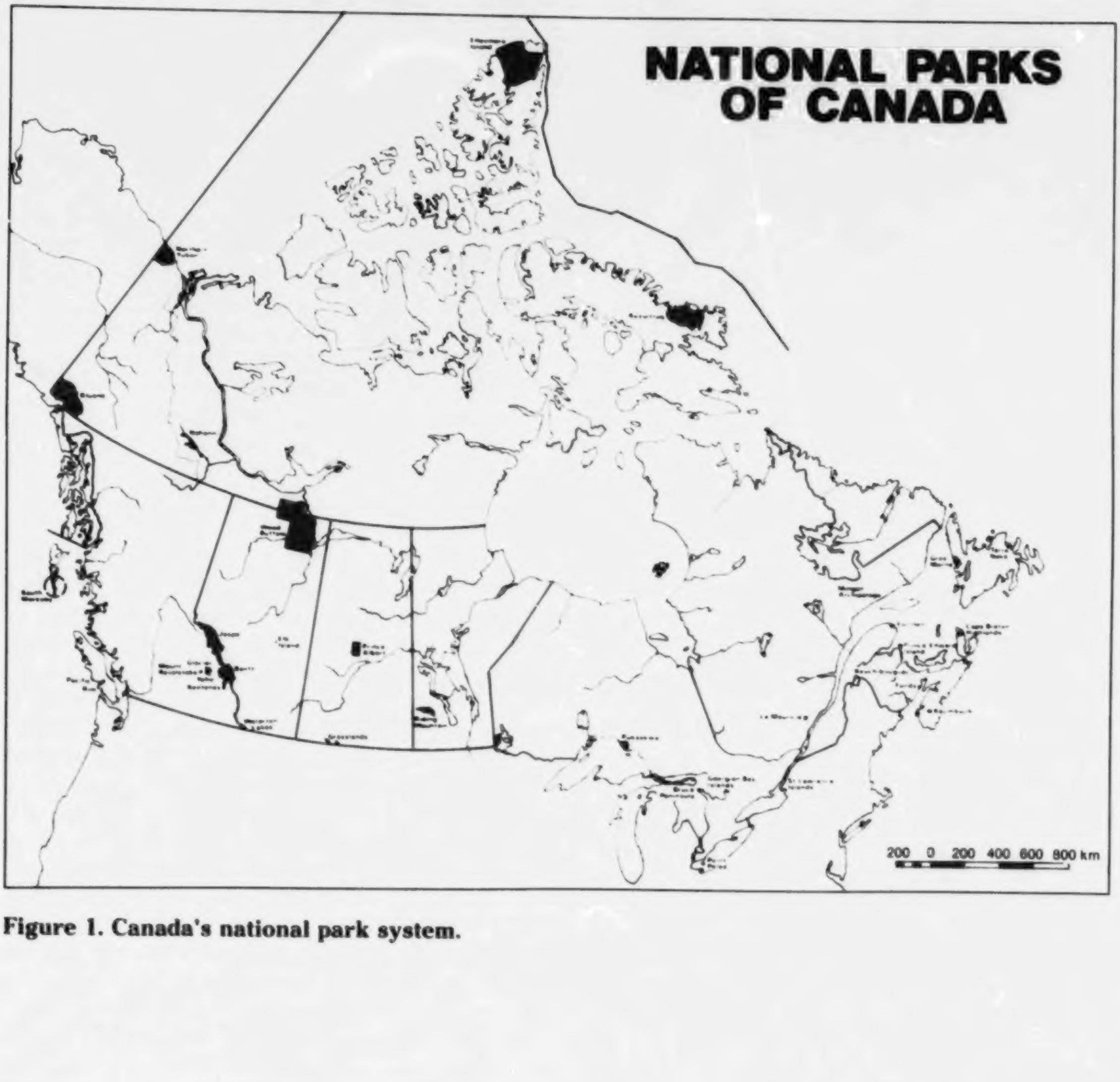

Figure 1. Canada's national park system.

THE BURNING QUESTION: A HISTORY OF FIRE IN THE PARKS

Rarely a public commodity, the internal debate in the CPS about ensuring that fire-dependent vegetation types are not forever denied their most vital process of renewal and diversity continues to this day. To put perspective on this question, it is useful to describe historic periods of fire in the parks. In this discussion we will emphasize the frequency of fire as described through fire cycle or burn-area statistics. Other elements of the fire regime such as fire intensity, depth of burn, fire size (Heinselman 1981), and the structure of biotic communities that the fire regime influenced (Bonnicksen and Stone 1982) must also be recognized as important.

Natural Fire Period

What is natural? is a topic of wide-ranging opinion (Kilgore 1985). We will modify a description provided by Van Wagner and Methven (1980) and define it here as a state of ecological integrity where native biotic communities are in equilibrium with long-term environmental processes. This is an ecological definition that does not differentiate between man-caused and lightning-ignited fires except in how they contribute to the fire regime. The natural period could be said to end at the time where modern technological man radically changes native biotic communities or long-term processes. This would have occurred prior to 1750 in much of eastern Canada, around 1900 in the western parts of the country, and is only now occurring in some parts of the north.

Numerous fire history and ecology studies (e.g., reviewed by Heinselman 1981; Kilgore 1981; Wright and Bailey 1982; Wein and MacLean 1983) provide us with information on the natural role of fire in Canada. Several of the studies cited in these reviews were conducted in national parks. In Table 1 we have applied available information on fire history to park ecological land classifications to generate preliminary estimates on the area of parks by fire cycle (as defined by Van Wagner 1978). These estimates may be particularly weak for the Atlantic and Quebec regions where few park-specific studies are completed. Although it is clear that some of Canada's park lands, being rock, ice, water, arctic, or alpine, have little or no history of fire, it is evident that large areas were profoundly influenced by fire during the natural period. Fire cycles may have been longest in the east with the majority of the areas vegetated by types with fire cycles greater than 100 years. The Ontario Region of the CPS is dominated in area by Pukaskwa which has a natural fire cycle of approximately 70-100 years. In the Prairie/Northern and Western regions, large areas are montane, aspen, or mixedwood boreal vegetation types with natural fire cycles of less than 100 years.

Applying the fire cycle concept further and assuming the mean annual area burned is equal to the total area in a fire cycle class divided by the mean of the class (e.g., 37.5 years for the 25-50 year class), we can generate the mean annual natural burn area for each park (Table 2). These preliminary estimates highlight the role of fire in the Prairie/Northern Region. During the natural period, lands now contained in these parks may have contributed over 80% of the expected CPS burn area.

Exploitation Period

Except in the north, few Canadian parks have escaped a period of exploitation by European man (R/EMS Research Ltd. 1988). Forests in almost all eastern parks were logged for over a century. Logging activity continued for decades in Riding Mountain, Prince Albert, Banff, and Yoho national parks and will continue by agreement to the year 2002 in Wood Buffalo. Many southern parks have also seen farming and stock grazing and in some cases, even mining. Often coincident with these exploitive uses was frequent man-caused fire. Even lightning-ignited fires may have been more extensive due to the slash from logging operations. The result of the exploitation period was often change in the structure of native biotic communities. For example, the forests now contained in La Mauricie National Park in Quebec likely once contained a large component of white pine. After 100 years of logging (1850-1971) and numerous fires, the forests of today are dominated by hardwoods such as birch and maple (Dryade Ltd. 1986).

Fire Control Period

Under the protection philosophy described earlier, the CPS has attempted to control most fires for over 100 years. In southern parks, fire control has been mostly successful. Burn area statistics from Banff (Table 3) are typical. White (1985a) does not attribute much of the reduction in burn area to direct fire-fighting. For most of the last 100 years, detection times were very long, and travel by boat, foot, and horse did not permit rapid initial attack. Rather than

Table 1. Past and recent fire history in Canada's national park system

Canadian Parks Service (CPS) National Park (NP) or National Historic Park (NHP)	Total area (km²)	Area of park (km²) by historic fire cycle (years)						No fire evidence (km²)
		1.25	25-50	50-100	100-300	300-500	500-1000	
Atlantic Region								
Terra Nova NP	396.5	-	25.0	250.0	83.4	-	-	38.1
Gros Morne NP	1 942.5	-	-	-	-	-	1 527.0	415.5
Cape Breton NP	950.5	-	-	-	200.0	680.0	-	70.5
Kejimkujik NP	381.5	-	-	200.0	165.0	-	-	16.5
Fundy NP	205.9	-	-	-	-	200.0	-	5.9
Prince Edward Is. NP	25.9	-	-	20.0	-	-	-	5.9
Kouchibouguac NP	238.8	5.0	5.0	-	125.1	50.1	-	53.6
Louisbourg NHP	7.5	-	-	-	5.0	-	-	2.5
Total region	4 149.1	5.0	30.0	470.0	578.5	930.1	1 527.0	608.5
Quebec Region								
La Mauricie NP	543.9	-	-	-	8.3	310.3	172.1	53.2
Forillon NP	240.4	-	-	-	-	-	230.0	10.4
Mingan Is. NP	150.7	-	-	-	-	-	53.3	97.4
Total region	935.0	0.0	0.0	0.0	8.3	310.3	455.4	161.0
Ontario Region								
Georgian Bay/Bruce NP	256.0	-	-	90.0	45.0	-	-	121.0
Point Pelee NP	15.5	-	6.0	8.0	-	-	-	-1.5
Pukaskwa NP	1 877.8	-	-	1 310.2	312.9	-	-	254.7
St. Lawrence Is. NP	7.6	-	-	3.0	4.0	-	-	0.6
Total region	2 156.9	0.0	6.0	1 411.2	361.9	0.0	0.0	377.8
Prairie/Northern Region								
Riding Mt. NP	2 975.9	1 415.0	370.6	243.4	750.0	-	-	196.9
Prince Albert NP	3 874.6	1 270.9	650.0	626.0	350.0	-	-	977.7
Wood Buffalo NP	44 807.0	5 000.0	1 505.5	13 979.3	18 871.3	-	-	5 450.9
Kluane NP	22 015.0	-	-	-	1 550.0	-	-	20 465.0
Grasslands NP	142.0	142.0	-	-	-	-	-	0.0
Nahanni NP	4 765.6	-	-	2 720.0	1 522.0	-	-	523.6
Batoche NHP	10.8	10.8	-	-	-	-	-	0.0
Ft. Walsh NHP	6.5	6.5	-	-	-	-	-	0.0
North Yukon NP	10 168.4	-	-	-	1 000.0	-	-	9 168.4
Auyuittuq NP	21 471.1	-	-	-	-	-	-	21 471.1
Ellesmere Is. NP	39 500.0	-	-	-	-	-	-	39 500.0
Chilkoot Trail NHP	150.0	-	-	-	50.0	-	-	100.0
Total region	149 886.9	7 845.2	2 526.1	17 618.7	24 043.3	0.0	0.0	97 853.6
Western Region								
Elk Island NP	194.3	190.4	-	2.1	-	-	-	1.8
Banff NP	6 640.8	-	157.3	1 871.5	2 014.4	-	40.8	2 556.8
Jasper NP	10 878.0	-	834.6	3 321.1	1 917.5	-	608.3	4 196.5
Revelstoke NP	292.6	-	-	100.0	100.0	-	-	92.6
Glacier NP	1 349.6	-	-	440.9	524.8	-	-	383.9
Waterton Lakes NP	525.8	32.7	198.7	70.0	70.0	-	-	154.4
Kootenay NP	1 406.4	-	350.0	350.0	350.0	-	-	356.4
Yoho NP	1 313.1	-	-	328.0	328.0	-	-	657.1
Pacific Rim NP	388.5	-	-	-	-	-	350.0	38.5
South Moresby NP	1 440.5	-	-	-	-	-	963.2	477.3
Rocky Mt. House NHP	8.0	-	-	8.0	-	-	-	0.0
Total region	24 437.6	223.1	1 540.6	6 491.6	5 304.7	0.0	1 962.3	8 915.3
Total CPS	181 565.5	8 073.3	4 102.7	25 991.5	30 296.7	1 240.4	3 944.7	107 916.2

Table 2. Mean annual fire history in Canada's national park system

Canadian Parks Service (CPS) National Park (NP) or National Historic Park (NHP)	Mean annual burn area (km²)			Mean annual number of fires		References for fire cycle estimates
	Natural historic	Wildfire 1950-88	Current PB[a]	Wildfire	PB[b]	
Atlantic Region						
Terra Nova NP	4.4	0.2	0.0	2.0	0.0	Heinselman (1981); R/EMS Research Ltd. (1988)
Gros Morne NP	2.0	0.0	0.0	0.5	0.0	
Cape Breton NP	2.7	0.1	0.0	4.0	0.0	Eastern Ecological Research Ltd. (1978)
Kejimkujik NP	3.5	0.0	0.0	2.0	0.0	Wein (1978, 1986)
Fundy NP	0.5	0.0	0.0	1.0	0.0	Wein (1978, 1986)
Prince Edward Is. NP	0.3	0.0	0.0	3.0	0.0	
Kouchibouguac NP	1.3	0.4	0.0	15.0	0.0	Wein (1986); R/EMS Ltd. (1988)
Louisbourg NHP	0.0	0.0	0.1	0.5	1.0	
Total region	14.7	0.7	0.1	28.0	1.0	
Quebec Region						
La Mauricie NP	1.0	0.0	0.0	4.0	0.0	Cogbill (1984); Dryade Ltd. (1986)
Forillon NP	0.3	0.1	0.0	2.0	0.0	Dryade Ltd. (1986)
Mingan Is. NP	0.1	0.0	0.0	1.0	0.0	Dryade Ltd. (1986)
Total region	1.4	0.1	0.0	7.0	0.0	
Ontario Region						
Georgian Bay/Bruce NP	1.4	0.1	0.0	3.0	0.0	
Point Pelee NP	0.3	0.1	0.0	0.8	0.0	Bartlett (1956); Mosquin (1988)
Pukaskwa NP	19.0	0.3	0.0	3.0	0.0	Lopoukhine (1987)
St. Lawrence Is. NP	0.1	0.0	0.0	1.0	0.0	Mosquin (1986)
Total region	20.8	0.5	0.0	7.8	0.0	
Prairie/Northern Region						
Riding Mt. NP	130.1	10.8	0.0	3.4	0.0	Heinselman (1981)
Prince Albert NP	129.1	4.8	0.0	5.0	0.0	Kiil et al. (1973); Cameron (1975)
Wood Buffalo NP	720.9	426.8	0.0	28.4	0.0	Heinselman (1981); Wein (1987)
Kluane NP	7.8	0.0	0.0	0.5	0.0	Hawkes (1983)
Grasslands NP	11.4	1.0	0.0	0.5	0.0	Wright and Bailey (1982)
Nahanni NP	43.9	2.3	28.0	0.5	2.0	Parks Canada (1983)
Batoche NHP	0.9	0.0	0.1	0.5	1.0	Redmann and Ripley (1976)
Ft. Walsh NHP	0.5	0.0	0.0	0.5	0.0	Scace (1978)
North Yukon NP	5.0	0.1	0.0	1.0	0.0	
Auyuittuq NP	0.0	0.0	0.0	0.0	0.0	
Ellesmere Is. NP	0.0	0.0	0.0	0.0	0.0	
Chilkoot Trail NHP	0.7	0.0	0.0	0.2	0.0	
Total region	1050.1	445.9	28.1	40.5	3.0	
Western Region						
Elk Island NP	15.3	0.1	0.5	2.0	5.0	Blyth and Hudson (1987)
Banff NP	39.3	0.2	10.0	8.0	2.0	White (1985a, 1985b)
Jasper NP	76.9	0.7	1.0	9.0	1.0	Tande (1979); Fenton (1988)
Revelstoke NP	1.8	0.3	0.0	3.0	0.0	Heathcott and Johnson (1987)
Glacier NP	8.5	1.3	0.0	9.0	0.0	Heathcott and Johnson (1987)
Waterton Lakes NP	9.2	0.1	0.0	2.0	0.0	Mackenzie (1973)
Kootenay NP	15.8	1.0	0.0	4.0	0.0	Masters, unpubl.[b]
Yoho NP	6.0	1.5	0.0	3.0	0.0	Tymstra (1988)
Pacific Rim NP	0.5	0.0	0.0	0.3	0.0	Kilgore (1981)
South Moresby NP	1.3	0.0	0.0	0.3	0.0	Kilgore (1981)
Rocky Mt. House NHP	0.1	0.0	0.0	0.3	0.0	
Total region	174.6	5.2	11.5	40.9	8.0	
Total CPS	1261.7	452.5	39.7	124.2	12.0	

[a] PB = prescribed burns.

[b] Masters, A.M., in progress. Fire history of Kootenay National Park. Environ. Can., Can. Parks Serv., West. Reg., Calgary, Alberta.

Table 3. Area burned and number of fires >40 ha in size per decade for Banff National Park (from White 1985a)

Decade	Area burned (ha)	Number of fires
1880-1889	37 050	>6[a]
1890-1899	18 600	9
1900-1909	16 050	12
1910-1919	3 300	6
1920-1929	10 950	9
1930-1939	8 050	6
1940-1949	4 200	2
1950-1959	0	0
1960-1969	500	1
1970-1979	45	1
Total	98 745	>52

[a] Poor historical records and reburning by later fires makes determination of actual number of fires difficult.

fire-fighting, it is likely that prevention of man-caused fires is one of the most effective elements of fire suppression programs. Whatever the means, there is no doubt that the area burned has been sharply reduced from the natural period in southern parks. Table 2 shows that for the last 30 years the area burned by wildfires (those on which suppression action is taken) is less than 10% of the area estimates for the natural period (excluding data from Wood Buffalo and Nahanni national parks).

In contrast to the results achieved in the south, fire control efforts in the northern boreal parks of Wood Buffalo and Nahanni have not substantially reduced fire activity. Table 4 provides statistics for Wood Buffalo for the period 1956 to 1985. Despite a serious effort to control fires, major areas burned. Likely the large size of this remote park (40 000 km^2), the prevalence of unpreventable lightning fire ignitions, and the flammability of the natural vegetation during drought years will continue to make it exceedingly difficult to control fire.

Ironically, where fire control has been successful, the product may be similar to the effects of exploitation in the sense that dramatic changes can occur in the structure of native biotic communities. Perhaps the best illustration of this has occurred in Waterton Lakes National Park (WLNP). Prior to effective fire control (about 1911), natural fire cycles in WLNP disturbed, on average, greater than 1% of the forest per year (Mackenzie 1973). Subsequent to fire control, the area disturbed per year has averaged 0.12%. The reduction in burning allowed the maturing of large stands

Table 4. Area burned and total number of fires per 10-year intervals for Wood Buffalo National Park

Years	Area burned (ha)	Number of fires
1956-65	30 968	51
1966-75	241 401	285
1976-85	1 007 959	517
Total	1 280 328	853

of lodgepole pine. By the late 1970s these stands were 70-100 years old. This provided excellent conditions for a mountain pine beetle infestation, which peaked in 1981 and resulted in over 50% pine mortality. Unlike fire-killed lodgepole forests, stands killed by mountain pine beetle may not regenerate again to pine (due to lack of seed source or seedbed), and we may expect a long-term change in the structure of forests in WLNP.

Entering the Fire Management Period

The revision of CPS policy in the late 1970s, concurrent with fire management innovations in the United States, stimulated serious questioning of the protection philosophy as a whole and fire control in particular. At the headquarters level, the CPS began a series of initiatives to implement fire management. These included a literature review of fire ecology (Revill and Associates 1978), a strategy paper for fire management (Van Wagner and Methven 1980), and the organization of workshops for fire management experts and senior parks staff in 1980, 1981, and 1984. This effort culminated in 1986 with the interim approval of the Fire Management Directive (2.4.4) by the Assistant Deputy Minister responsible for the CPS. This directive recognizes that fire is an essential process in many park ecosystems; however, fire control will remain a priority to protect park facilities, visitors, and neighboring lands. Prescribed fire use may be authorized for vegetation management objectives. Because the biotic effects of fire are independent of the ignition mode, prescribed fires may be random (by lightning or unplanned man-caused ignitions) or planned by park staff. The mode of ignition shall be chosen that best achieves objectives while minimizing costs and threats to other values.

Meanwhile, in the parks, Forestry Canada (then the Canadian Forestry Service) provided early assistance in carrying out experimental planned-ignition prescribed fires in Jasper, Elk Island, and Prince Albert national parks. Unfortunately, in almost all cases the CPS could not sustain these programs. Our expertise, ecological understanding, and professional commitment was inadequate. Furthermore, the initial burns were often small and limited to preserving select vegetation communities (e.g., fescue grasslands). To many managers, these site-specific fire management goals seemed unreasonable for park-wide application in the large parks of the CPS. A more holistic view of integrating fire into the vegetation and landscape as a whole was needed. Trottier (1985) concluded his evaluation of the by-then defunct Prince Albert burning experiment by stating, "It would not be logical to devise . . . a (prescribed burning) program in the absence of an overall vegetation management plan for the park because the grassland cannot be managed outside the context of other vegetation types . . ."

WARMING-UP:
CURRENT FIRE MANAGEMENT INITIATIVES

Current efforts at implementing fire management in the CPS are marked by two characteristics. First, successful program managers recognize that fire management cannot proceed without some preconception of vegetation management objectives at the ecosystem level (Van Wagner and Methven 1980; Lopoukhine and White 1985). Secondly, as the understanding of the importance of fire in our ecosystems increases, there has been commitment from CPS staff to develop professional fire management capabilities. This has resulted not only in fire studies and prescribed fire experimentation but also increased emphasis on basic fire control.

At the Park Level

We will use a generic time-action schedule (Table 5) to describe a process that an individual park can utilize to begin fire management. This planning schedule emphasizes the need for sound fire control capability before proceeding toward fire management. Knowledge of park vegetation ecology and fire weather and potential behavior must then be assembled to develop initial vegetation management objectives. This process could take several years if studies are a required precursor or be compressed into less than one year if the knowledge of selected park staff along with other experts is combined to work out solutions in a series of workshops. A 5-year plan can then be developed, which in some parks could encourage the use of experimental prescribed fire as a means of evaluating long-term fire use. After several years of practical experience with fire use, it is likely that an understanding of fire will have increased to a point where a new plan would be necessary to guide the program for another period of time.

Current progress of parks in the generic schedule is shown at the bottom of Table 5. In general, western parks (e.g., Elk Island, Banff, and Jasper) are the most advanced. Fire history studies and evaluations of

Table 5. Generic time-action schedule for implementing fire management in the Canadian Parks Service

Item	Years from start												
	1	2	3	4	5	6	7	8	9	10	15	20	25
1. Acknowledge fire management	•												
2. Write fire mgmt. into PC program	•												
3. Write preliminary fire mgmt. plan	•												
4. Prepare funding requests	•												
Fire Control													
5. Suppress all fires—no fire use	•	•	•	•									
6. Develop escaped fire sit. analysis		•											
7. Designate fire control warden	All years												
8. Train staff in basic fire control	All years												
9. Maintain initial attack crew	All years												
10. Monitor fire weather	All years												
11. Assess daily level of readiness	All years												
12. Fire detection	All years												
13. Maintain equipment	All years												
14. Fire prevention program	All years												
15. Interagency agreements	All years												
16. Suppress unwanted fires only					•	•	•	•	•	•	•	•	•
Fire History/Ecology Evaluation													
17. Fire history study		•	•										
18. Vegetation change analysis			•										
19. Estimate fire cycles for park veg.				•									
Fire Weather/Behavior Evaluation													
20. Key veg. types to CFS FBP		•											
21. Computerize historical weather			•										
22. Analyze potential fire behavior			•										
23. Adjust man-up procedures				•									
24. Develop fire use prescriptions				•									
25. Improve fire weather network	As required												
Fire Management													
26. Develop staff expert.-educ. leave		•	•	•									
27. Designate fire mgmt. units					•								
28. Designate fire mgmt. zones					•								
29. Designate PB units					•								
30. Write 5 yr. mgmt. plan					•								
31. Environmental screening					•								
32. Public information				•	•	•	•	•	•	•	•		
33. Conduct experimental burns					•	•	•	•	•	•	•		
34. Rewrite fire mgmt. plan										•	•	•	•
1988 NATIONAL PARK STATUS IN PROGRAM													
Kouchibouguac		•											
La Mauricie				•									
Pukaskwa			•										
Riding Mountain			•										
Prince Albert				•									
Wood Buffalo				•									
Batoche			•										
Elk Island							•						
Waterton Lakes		•											
Banff							•						
Jasper					•								
Revelstoke/Glacier			•										

potential fire behavior are complete, and the first 5-year management plans have been approved (Masters 1987). These parks now burn over 1000 ha/yr with planned-ignition prescribed fire.

Moving eastward, fire management progress is slower. Fire history studies are difficult in aspen forests that dominate considerable areas of Prince Albert and Riding Mountain national parks. In Ontario, Quebec, and the Atlantic provinces, a long period of exploitation prior to protection makes it nearly impossible to reconstruct through study the structure and function of natural ecosystems. Furthermore, the frequency of lightning-ignited fires decreases in the east. Humans may have long been a significant ignition source. Opinions remain divided on the question of whether this ignition mode should be continued to maintain or recreate native biotic communities (Mosquin 1988).

In the Regional and National Offices

Increasing field-level implementation of fire management requires more emphasis in administrative coordination. For example, all CPS regional offices are designating regional fire management officers to assist in planning and coordinating fire activities. The Western Region has committed significant effort to develop a consistent fire management strategy for parks (Masters 1987). The Prairie/Northern Region is hiring a specialized fire management officer to aid parks in implementing Directive 2.4.4.

The Natural Resources Branch in headquarters has hired a national fire management coordinator. Emphasis at this level has been on developing a service-wide fire preparedness system based on use of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks et al. 1989), increased communication and mobility of specialized staff between parks and regions, and standard financial procedures for accessing fire presuppression and suppression budgets.

An Independent Assessment

As a condition to interim approval of the Fire Management Directive, CPS senior management required that qualified outside-agency experts should make an assessment of fire management in the CPS and report back by March 1989. The Natural Resources Branch contracted to Resource/Environment Management Systems (R/EMS) Research Ltd. of Fredericton, New Brunswick, to undertake this task. In 1987 the consultants conducted detailed inspections of operations within 12 important "fire parks" in the national park system. Canadian Parks Service staff at all regions and headquarters were interviewed. Available documentation relating to fire and general ecosystem management was reviewed.

For the past several months CPS staff have been digesting the assessment report (R/EMS Research Ltd. 1988). The full impact of the analysis will likely be profound. While praising some aspects of our program, the outside experts documented serious deficiencies. Foremost was the continued difficulty the CPS is having in recognizing fire as a major ecosystem process. This is reflected in a lack of fire management objectives and staff commitment in several parks. Further, the CFFDRS is not being fully utilized to regulate levels of readiness. This has resulted in relatively inflexible fire preparedness that needs a major overhaul. And in some parks, the rapid initial attack concept has been crippled by a lack of helicopter support. The assessment concludes that "there are pockets of expertise in the Canadian Parks Service that are second to none in the world, and the service is poised to take a leading role in active landscape and fire management. It is equally poised to fail…"

ON-THE-LINE: A SUPERINTENDENT'S VIEWPOINT

By D.L. Day

On September 7, 1987, I signed the approval document for the 2300-ha Minnewanka I prescribed fire. It seemed that the CPS had made astounding progress from a time, less than a decade before, when I had worked with headquarters staff to develop a new fire policy. At that time the idea of a planned-ignition prescribed fire of this size anywhere on CPS lands seemed a long way off, especially in the Bow Valley of Banff National Park.

As it turned out, we weren't ready to attempt the Minnewanka I unit. On September 16, a small crew attempted to burn out a fire guard along our boundary with the province of Alberta. Their task was exceedingly risky, yet they did not have a helicopter on site. The fire spotted onto provincial lands. Only the late hour of the day and favorable winds prevented a major escape. Then, 2 weeks later, the upwind fire guard, which had been burned out several days before, was rekindled by drying winds and resulted in a fire run into the unit. Because the downwind perimeter was not yet completely burned out, suppression action was required. Attempting to burn the guards for the unit had now resulted in two wildfires, had disrupted normal park operations, and had cost over $50,000. We were left with some disturbing questions as to what went wrong.

My staff did a no-holds-barred analysis on the fire. The major weakness identified was the shortage, in the park, of qualified staff at the fire command team level. This would seem surprising given that Banff has the largest available pool of park wardens (over 50) and routinely sends wardens to advanced fire-training courses. Banff also maintains a rigorous in-park training program that involves another 100 park staff and conducts at least two prescribed fires per year. Yet, given other demands on our staff's time and the infrequency of extreme fire activity, we cannot maintain adequate training and experience levels to be self-sufficient in fire management.

This realization has broad ramifications not just for Banff but for the whole CPS. Banff has the biggest staff pool of any park in Canada. If we cannot be self-sufficient for fire command and fire-fighting forces, I doubt that any unit in the CPS can be. Two solutions are obvious. First, we must do much more to share staff and other specialized fire resources between parks. The CPS has a unique fire management mandate that is not shared with our neighbors. Thus, if our staff are to develop expertise in low-impact fire-fighting methods and prescribed fire in standing forests they must be encouraged to participate in operations in other parks. This is a situation where the broad geographic spread of the CPS can be used to advantage. Even if a park experiences several wet years, staff could maintain expertise by helping parks in drier areas of the country. Secondly, once our staff become competent both at contributing to operations in other parks and at utilizing outside assistance, the CPS should make a much stronger thrust at interagency cooperation. It may not be possible at all times for our immediate neighbors to help us with our fire management operations due to burning conditions on their own lands, but this can be very cost-effective and should be encouraged.

I suspect that the ideas expressed above are old news to most other fire agencies, but in the CPS we have made a tradition of park self-sufficiency. In many facets of our operations it is the best way to get things done but not for fire management.

In Banff we are putting this new philosophy into practice. On April 17, 1988, we returned to Minnewanka I but this time with a fire command team selected from CPS fire staff across the country. At 1500 Mountain Standard Time a convection column rose nearly 3000 m over the unit, and by the end of the day over 1200 ha were burned—much of this as a crown fire. As with any well-planned (lucky?) prescribed fire, it rained the next day. Our costs were under $15,000.

Beyond these growing pains, my experience with fire in Banff has not been unpleasant. Thousands of visitors and park residents cannot fail to observe (and experience) the smoke from prescribed fires in progress. The dramatic impacts of a recently burned area are seen by many, but there are very few unfavorable comments. Surprisingly, almost all of our varied clientele seem to appreciate the importance of our task. I attribute this favorable response to the continued efforts of Banff staff in spreading the word about natural fire management.

CONCLUSIONS

In the last few years, the CPS has made substantial progress in maintaining ecological integrity through the management of fire. The organization has become surprisingly well adapted to the notion that "keeping the flame" is essential if parks are to ensure the propagation of many forest types. The rigorous insistence on developing a scientifically sound, safe, and cost-effective approach to fire management is the basis for this forward-looking direction adopted by the CPS.

Although a consistent policy line has been adopted, putting its most fundamental tenets into play has been difficult. Even in national parks such as Banff, where superintendents have actively supported contemporary fire management direction, progress has been slow. As the R/EMS Research Ltd. (1988) assessment has identified, parks have not fully integrated the role of fire into their resource management programs. But it is partly as a result of continued research into prescribed burning that the CPS has come to grips with the need to better balance its energies in fire management. The recent initiative to develop a national CPS fire preparedness system is undergoing field trials in 1989 and is expected to sharply upgrade the organization's ability to respond effectively to fire, no matter what the source of ignition.

Significant challenges face park staff in the years ahead. Most national parks are at least 10 years away from having comprehensive fire management plans in place. In the interim we remain custodians of a massive area of forest prone to explosive crown fire. In practical terms, the CPS faces a tremendous challenge in securing the monies and human skills to build its fire preparedness to the point that ecologically based practices can be applied with sufficient vigor to produce long-term benefits. Despite its avowed policy, the organization presently lacks the financial "comfort" to fully respond to fire's role. In such an environment it is understandable that senior CPS managers must exercise extreme caution in launching aggressive programs such as ecological fire management.

Despite these constraints, the CPS is dedicated to meeting its mandate for national parks. Initiatives over the next several years will focus on research, planning, establishing preparedness, public relations, and modest field trials. By the turn of the century, the Canadian Parks Service aims to be able to ensure that future generations will be able to see fire-dependent biotic communities maintained in a natural environment. Vive la diversité!

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FOREST INDUSTRY INVOLVEMENT IN FIRE PROTECTION: AN ALBERTA PERSPECTIVE

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ABSTRACT

Forest industry involvement in wildfire protection reduces fire risk and potential economic losses. This paper highlights Weldwood's Hinton Division involvement and goals towards wildfire control and management as a Forest Management Agreement (FMA) operator. Fire control agreements between the Government of Alberta and FMA holders specify mutual commitment and individual obligations for the prevention and control of wildfire on FMA areas. Primary responsibility for fire protection on an FMA area rests with the Alberta Forest Service, but companies must also maintain their own fire suppression organization, trained and equipped to take action where necessary on fires occurring in their respective areas or within the sphere of interest. Additionally, company and government organizations must complement each other and create an environment where cooperation and communication flourish.

INTRODUCTION

In Alberta, Forest Management Agreement[1] (FMA) area operators are responsible for and contribute to many phases of forest management within their respective areas. Included in this wide spectrum of management objectives is wildfire protection. Holders of FMAs have a mandate to manage the forest resources entrusted to them on a sustained yield basis. Industry involvement in wildfire protection enhances existing government fire protection systems by providing supplemental manpower and equipment. Industry personnel are generally familiar with the geography, topography, vegetation, and transportation systems within their specific work areas and are often organized into crew or team configurations. This type of work environment coupled with associated heavy equipment and strategically positioned fire caches provide a major on-site fire suppression resource that may be used for initial attack or mainstream fire-fighting resulting in reduced wood fiber loss due to wildfire.

In Bishop and Dasti's (1986) paper on fire prevention and forest operations, Bishop outlined three principal objectives of forest industry involvement in a wildfire protection: 1) practicing fire prevention, presuppression, and 3) providing backup. These objectives hold true in Alberta and apply to FMA holders. In addition, FMA operators are obligated to take immediate fire suppression action whenever any wildfire is detected on the FMA[2] area.

The past 10 years have seen an increased demand for government and industry to improve provincial forest protection systems. The severe fire years of the early 1980s provided government and industry alike with an opportunity to evaluate the interaction between their organizations. This paper focuses on one of Alberta's FMA holders, Weldwood of Canada Limited, Hinton Division (Fig. 1) and the commitment it has made to wildfire protection. The company's historical background of involvement with fire protection is presented prior to detailing the company's responsibilities in wildfire prevention and suppression. Specific company suppression objectives and procedures are discussed followed by fire organization and risk reduction in forest management planning. Problems encountered and conclusions complete the paper.

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[1] Government of the Province of Alberta. The Forests Act, Forest Management Agreement (O.C. 290/88). 1988. An FMA area is a tract of forest land over which a company has been given the management rights for establishing, growing, and harvesting trees on a perpetual growth yield basis for a defined period of time.

[2] Pelican (Spruce) Mills Limited Forest Fire Control Agreement 1988, Page 5; Weldwood of Canada Limited, Alberta Waferweld Division, 1988, Page 5; Weldwood of Canada Limited, Hinton Division, 1988, Page 5.

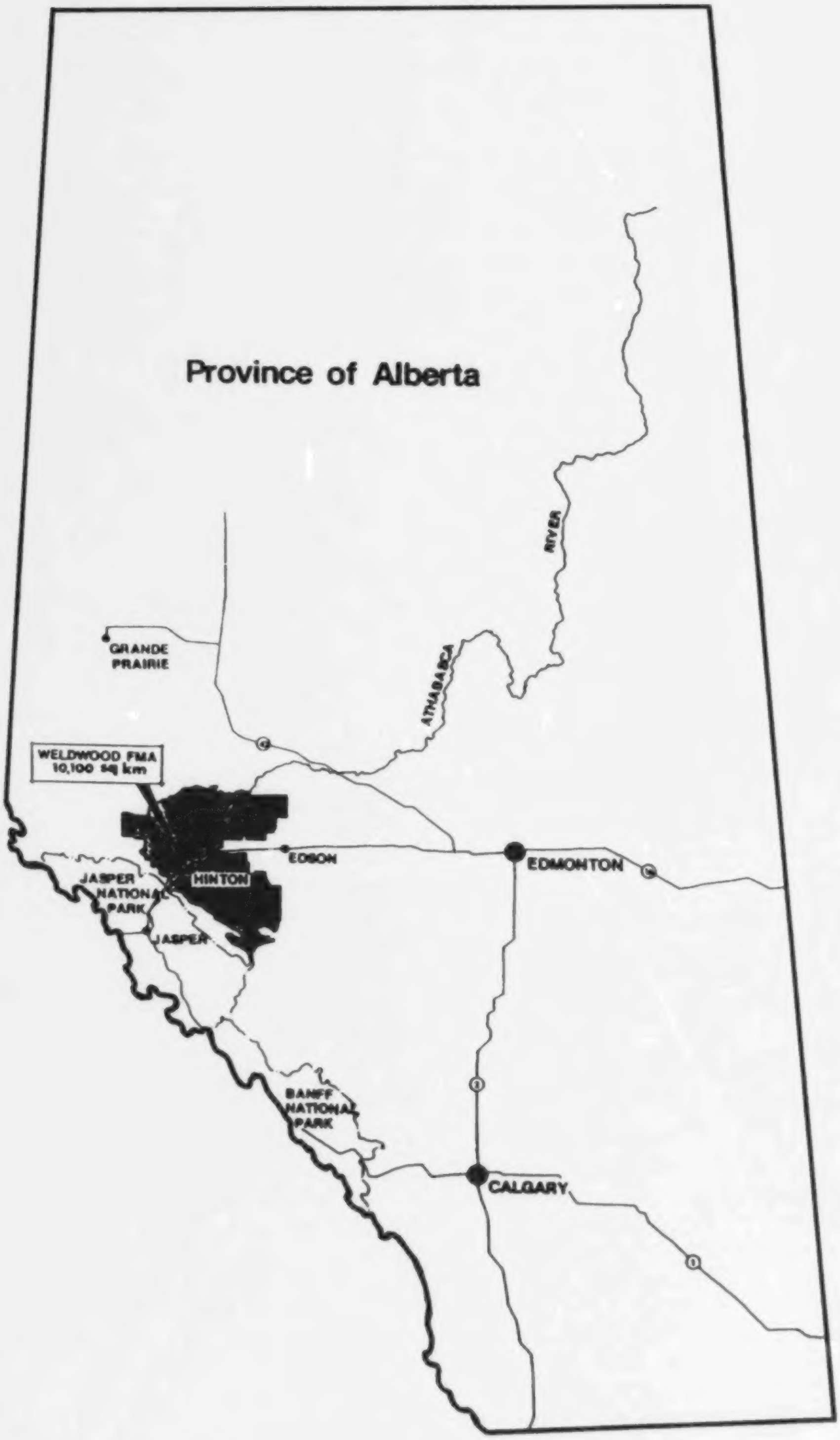
Province of Alberta
RIVER
GRANDE PRAIRIE
ATHABASCA
WELDWOOD FMA 10,100 sq km
EDSON
EDMONTON
JASPER NATIONAL PARK
HINTON
JASPER
BANFF NATIONAL PARK
CALGARY

Figure 1. Location of the Weldwood of Canada Limited's (Hinton Division) Forest Management (FMA) area in west-central Alberta.

HISTORICAL BACKGROUND OF WELDWOOD'S HINTON DIVISION INVOLVEMENT IN FIRE PROTECTION

In 1954, North Western Pulp and Power (now Weldwood of Canada Limited, Hinton Division) and the Government of Alberta signed the first Forest Management Agreement in Alberta. This agreement gave the company the right to harvest and manage the timber from its 780 000-ha lease. Additionally, the company assumed many of the resource management responsibilities historically held by the Alberta government. Included in these responsibilities were forest management plan development, road construction, and reforestation.

Preparation and groundwork for the first Fire Control Agreement (FCA) began in 1961. Final approval of the negotiated agreement was given in 1964. This agreement outlined requirements and methodology for the annually submitted company Fire Control Plan (FCP), government and company fire prevention and suppression responsibilities, payment for wildfire suppression costs, and settlement of disputes. Prior to signing the agreement, company-prepared FCPs were submitted in compliance with the provincial fire prevention regulations applicable to all leaseholders of crown timber limits. Since the signing of the first FCA, the province and company have amended the agreement several times to more effectively address and complement technological advances and fire presuppression and suppression priorities. On June 15, 1988, Weldwood's new Forest Management Agreement was signed expanding the FMA to 1 012 000 ha. This will necessitate an adjustment in the existing FCP to accommodate increased equipment and fire training.

The company has been actively involved with wildfire suppression since the early 1960s. Action has ranged from initial attack to line, plans, and service functions on campaign fires. A majority of the company's fire-fighting action has taken place within the FMA area and a surrounding sphere of interest. On occasions when the province has experienced severe fire years, company harvesting crews and supervisory staff have been exported to other parts of the province to action campaign fires. This was the case during June and July of 1982 when harvesting crews and foremen were used to action fires in the Peace River and Slave Lake forests. The number of documented Alberta Forest Service (AFS) and municipal (i.e., sphere of interest) fires the company has been actively involved in suppressing since 1980 is summarized in Table 1.

Table 1. Number of fires in FMA area and adjoining lands suppressed by Weldwood in cooperation with other agencies

Fire season	Number of Fires Alberta Forest Service	 Local municipalities
1980	12	2
1981	6	3
1982	1	0
1983	0	0
1984	5	4
1985	2	0
1986	0	0
1987	8	3
1988	7	2

COMPANY RESPONSIBILITIES IN WILDFIRE PREVENTION AND SUPPRESSION

The degree of company involvement in forest protection activities is governed by the FMA and FCA. The individual FCAs and FMAs are negotiated by the provincial government and designated FMA operators. These joint agreements outline the specific fire prevention and suppression responsibilities of the Government of Alberta and FMA holder. The Forest Management Agreement (Government of the Province of Alberta, The Forests Act, Forest Management Agreement O.C. 290/88) defines the responsibilities in the following way:

1. The Minister agrees to provide and maintain an organization of men and equipment necessary for the protection of the forest from and suppression of forest fires on the forest management area and, except as herein otherwise provided, to pay the cost of fighting any forest fire that originates on the forest management area on the understanding that the Minister will not be liable for damages to the company resulting from a failure to prevent, control or suppress any fire.

   Government payment for company fire-fighting costs are based on the Provincial Fire Protection Wage and Rental Regulations.

2. The company shall pay the cost of suppressing any forest fire that originates on the forest management area if the fire is caused by or arises out of any of the operations or activities conducted on the forest

management area by the company, its employees, agents or contractors; provided, however that in no event shall the liability of the company exceed the liability provided for in a separate Fire Control Agreement which may be negotiated and entered into by the Minister with the company. Until such time as a Fire Control Agreement has been entered into, the company agrees to have on hand in good working order such fire-fighting equipment and shall train such employees in fire suppression as specified by the Minister. If the cause of any fire is disputed by the company, the dispute shall be resolved by means of civil suit in the courts of Alberta.

3. The company shall not be liable for loss of or damage to Crown timber by fire that is caused by or arises out of any of the operations conducted on the forest management area by the company, its employees, agents or contractors.

   Costs incurred directly or indirectly by any operations or activities conducted on the FMA by the company or its contractors are categorized according to the following:

   i) If a fire on the FMA is caused directly or indirectly by any of the operations or activities conducted by the company or its contractors, the company shall pay 50% of the cost of suppressing the fire. The cost for any one fire shall not exceed the maximum charge calculated in accordance with the following annually adjusted formula:

      Example:

$$\text{1987 maximum charge per fire} = \frac{\$55{,}860^{3} \times \text{1986 Statistics Canada annual implicit price index}}{\text{1981 Statistics Canada annual implicit price index-base year}^{4}}$$

   ii) If a fire on the FMA is caused directly or indirectly through an *intentional* or *negligent* act by the company or its contractors, the company shall pay all fire suppression costs less any amounts that the government decides to waive.

Weldwood must pay the Alberta government an annual forest protection charge for every square kilometre within the FMA. This charge is based on the annually adjusted Statistics Canada implicit price index on gross domestic product for government current expenditures on goods and services.

Total 1987 forest protection charges for the Weldwood Hinton Division FMA were approximately \$200,000 on 7652 km². The new forest management agreement specifies the following values for forest protection charges:

$$\text{1988 forest protection charge} = \frac{\$26.06/\text{km}^2 \times \text{1987 implicit price index}}{\text{1986 implicit price index}}$$

Prior to March 1st of each year, the company submits to the AFS Forest Superintendent for the Edson Forest a Fire Control Plan (FCP) covering the FMA for the ensuing fire season. This plan is then reviewed by the AFS and revised or accepted. Revisions are completed to the mutual satisfaction of both parties prior to final approval.

Annual reclamation plans address hazard reduction and silviculture requirements showing exact locations of proposed burning, potential areas for holdover fires and supplemental scanning requirements. The reclamation plan provides additional information for the Road Retention Program, which is being updated on a regular basis. The road plan indicates current access status (i.e., 2 × 4 truck, 4 × 4 truck), of company and noncompany roads. This information is incorporated onto a fire access map for use by AFS and company personnel.

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[3] Calculation of \$55,860: The original FMA operator cost for a fire was based on 50% of the average incurred suppression costs and was set at \$30,000 in 1975. The old implicit index in place, prior to 1987, converted the \$30,000 (1975 base year cost) to \$55,860 in 1981 dollars. The formula used for this conversion was

$$\frac{\$30{,}000.00 \times 290.4 \text{ (1981 implicit index)}}{156.0 \text{ (1975 base year implicit index)}} = \$55{,}860.00$$

\$55,860 is the base value in 1981 dollars and is used with the current implicit price index for government current expenditures on goods and services—Gross Domestic Product as per Statistics Canada, 1987.

[4] 1981 is presently used in the formula as the new base year with an index value of 1.00, AFS; Statistics Canada, 1987.

COMPANY FIRE PREVENTION AND SUPPRESSION OBJECTIVES AND PROCEDURES

It is the mutual goal of the AFS and Weldwood to suppress fire in the initial stages, preferably at "spot" size whenever possible. On any fire within the FMA area, the company will take immediate action using all necessary available resources in the vicinity of the fire to contain and suppress the fire.

The annual FCP is for all company supervisory personnel and incorporates the following forest protection objectives: detection, communication, prevention, presuppression, and suppression of wildfires. Company facilities for implementing protection measures are described in detail. The FCP indicates how the company will endeavor to coordinate its fire control activities with those of the AFS. The company's suppression organization shall be under the control of the AFS whenever the latter is acting to suppress any fire on the FMA or within the sphere of interest.

Company presuppression and mainline suppression objectives are explained in the FCP. Table 2 provides a list of topics detailed in the FCP. Table 3 shows reference information such as AFS and company organizational charts and job responsibilities, company fire regulations, inventory and equipment lists and dispositions, monthly operations reports, company weekend duty rosters, emergency telephone numbers, etc. Specific company procedures for reporting and actioning wildfires are given in Table 4. The Canadian Forest Fire Danger Rating System (CFFDRS) (Canadian Forestry Service 1987) is utilized by Weldwood as a guide to presuppression activities (e.g., fire prevention).

Forest Management Agreement operators make the greatest contribution to wildfire suppression through ground support of manpower and equipment. Table 5 gives a basic list of fire equipment that the company keeps in inventory. At Weldwood, Forest Resource Department personnel are trained on an ongoing basis, and equipment is being continually modified and adapted to meet today's needs. Currently all mobile fire-fighting equipment has been modified for forest fire foam applications and rural-urban interface compatibility.

Table 2. Topics detailed in the 1988 fire control plan

1. Manpower
    a. Company Forest Protection personnel
    b. Supervisor responsibilities and organizational charts
    c. List of Weldwood personnel who will act as Fire Guardians
    d. Contact personnel for alerting families of Weldwood personnel working on a fire
    e. Bush workers: manpower numbers and respective work locations
    f. Wood hauling
        - Manpower numbers and respective work locations
        - Radio allocations
        - Shutdown periods
    g. Initial attack (I.A.) crew: 4-person crew
    h. Tree planting: manpower numbers and respective work locations
    i. Harvest crew and loading supervisors: manpower numbers and respective locations
    j. Commuting centers: marshaling points for crews, Hinton and Edson
    k. Operating flexibility: where woodland operations will be located on a weekly or monthly basis

2. Fire-fighting equipment
    a. Tanker units
        - Type of tankers and number of wheeled units
        - Wheeled tanker locations
        - Equipment on tankers
    b. Fire-fighting equipment
    c. Camping equipment
        - Type of fire camp equipment
        - Number of camp kits
    d. Heavy equipment
        - Company and privately owned
        - Type of equipment

3. Communications
    - Radio frequencies and call signs
    - Mobil telephones: mobil, portable and base station numbers and locations
    - Daily and 24-hour coverage

4. Fire standby
    - Company I.A. crew work schedules, job objectives, and interaction with AFS I.A. crews
    - Weekend duty person

Continued on next page

Table 2. Continued

5. Patrols
   - Type of patrols
   - Patrol routes
   - Interaction with AFS

6. Forest closure
   - Conditions for closure
   - Interaction with AFS

7. Training

   a. Coordinators and supervisors
      - Trained by AFS up to sector boss level
      - Receive industrial fire certification: based on fire experience and academic fire training

   b. Pump crews
      - In-house training of pump crews
      - Within each harvesting crew are individuals trained to work on fire pump crews

   c. Initial attack crew
      - Lead hand on company 4-man I.A. crew completes annual AFS initial attack crew leader course
      - All company I.A. crew members complete annual AFS initial attack crew member course
      - I.A. crew works in cooperation with District AFS I.A. crews in fire action, standby, loaded patrols, etc.
      - Company I.A. crew normally actions second fire. AFS I.A. crew actions first fire

   d. Fire-fighters
      - Consists of harvesting crew personnel
      - Currently most have fire line experience
      - Receive on-the-line forest fire and fire extinguisher training

8. Weather: received from AFS as required

9. Fire regulations
   - Standard regulations for all forest resource department personnel and contractors
   - Penalties for violating government Forest and Prairie Protection Act, 1971

10. Access roads and water sources
    - Annual road survey carried out in conjunction with Weldwood's road retention plan
    - Dependable water sources are marked on maps

11. Travel time map
    - AFS travel time map is used
    - Kept current as part of the road retention program

12. Visible areas
    - AFS maintains all fire lookouts
    - Tower locations are plotted on maps
    - Visibility areas are based on AFS maps

13. Barrier locations
    - Company gates
    - Accessed by AFS and key company personnel

14. Operating compartments: maps of proposed harvesting areas

15. Hazard reductions and reclamation
    - Joint AFS-Weldwood field survey carried out
    - Maps show location of hazard reduction burning as a result of company operations such as mechanical harvesting, hardwood clean-up, thinning, blowdown, and red belt
    - All slash burning is carried out in cooperation with the AFS

16. Company procedures for reporting and actioning wildfire

    a. General job responsibilities: fire discovery and reporting
    b. Fire suppression procedures
    c. The proposed eight fire-fighting commandments
    d. The present 10 standard fire-fighting orders
    e. The present 13 situations that shout, "Watch out!"

Table 3. Reference information included in the fire control plan

1. Weldwood of Canada Limited, Hinton Division, Forest Resource Department fire control organization and general personnel job responsibilities
    a. Headquarters level service organization - chart
    b. Headquarters level service organization - general duties
    c. District 2 and 4 sector level fire organization
    d. Districts 1, 2 and 4 sector level fire organization
    e. Division level fire control organization
    f. Division level fire certification list
    g. Fire guardian responsibilities
2. The Alberta Forest Service fire control organization and personnel job responsibilities
    a. Alberta Forest Service fireline organization - general
    b. Alberta Forest Service fireline organization - charts
    c. Alberta Forest Service fireline organization - specific job duties
    d. Alberta Forest Service fireline organization - typical duty day schedules
    e. Alberta Forest Service - position duties check list
    f. Alberta Forest Service - presuppression preparedness system
3. Weldwood of Canada, Hinton Division, Forest Resource Department fire regulations
4. Weldwood of Canada Limited, Hinton Division, Forest Resource Department fire equipment lists: list of contents in fire fighting kits
5. Weldwood of Canada, Hinton Division, Forest Resource Department fire-fighting equipment on inventory
6. Monthly strength status form
7. Heavy equipment disposition
    a. Weldwood's Forest Resource Department: light and heavy equipment disposition
    b. Privately-owned light and heavy equipment in the Hinton area
    c. Privately-owned heavy equipment disposition, operators and telephone numbers in the Edson/Hinton area
8. Weldwood of Canada Limited, Hinton Division, Forest Resource Department: holiday and weekend fire duty roster, job requirements and officers' responsibilities
    a. Holiday and weekend: emergency fire duty roster
    b. Holiday and weekend fire duty roster: general requirements and responsibilities
    c. Holiday and weekend fire duty roster: specific job duties
    d. Beauford wind scale
9. Weldwood of Canada Limited, Hinton Division, communication network
10. Fire extinguisher and fire equipment regulations for all company, contractor, and subcontractor equipment working on Weldwood's Forest Management Area
11. Emergency telephone numbers
12. Forest management area road access map
13. Operating compartments and maps
14. Map showing high hazard areas
15. 1988 reclamation plan: indicating hazard reduction areas and proposed treatments

Table 4. Specific Weldwood procedures for reporting and actioning wildfires

1. GENERAL JOB RESPONSIBILITIES: Fire Discovery and Reporting

When you discover a fire:

a. Contact the company headquarters or Alberta Forest Service as soon as possible. Give the following information:
  i. your name
  ii. fire location
  iii. fire size
  iv. type of fire (ground, surface, or crown)
  v. rate of spread (slow, moderate, fast)
  vi. fuel types (slash, standing timber and density, grass, etc.)
  vii. pertinent weather (wind direction, wind speed)
  viii. topography fire is burning in (flat, uphill, downhill)
  ix. water sources available
  x. an estimate of equipment and manpower needed for control
b. Where possible, take immediate initial suppressive action.

When receiving a fire report:

a. Contact the company:
  i. Forest protection coordinator, failing him,
  ii. Forest protection supervisor, failing him,
  iii. Lands management superintendent, failing him,
  iv. Land use coordinator
b. Contact the Alberta Forest Service (giving pertinent details) at:
  i. Hinton: 856-2400
  865-8267
  865-3822
  ii. Edson: Fire control 723-8379
  Fire control dispatcher 723-8506
  Radio room 723-8508
  723-8507
c. Give complete cooperation and assistance to Alberta Forest Service personnel.

Note: Relay necessary information as stated in 1(a) above.
During fire emergencies, the Alberta Forest Service and helicopter companies may require access to the fire warehouse compound and heliport. During these situations, the AFS and helicopter personnel are to be allowed access to this area.

2. FIRE SUPPRESSION PROCEDURES

When you action a fire:

a. Notify the rest of the crew and begin suppression work immediately.
b. Designate one person to immediately notify the company forest protection section and/or the Alberta Forest Service of the fire and pertinent fire data such as:
  i. Fire size
  ii. Type of fire
  iii. Fuel type
  iv. Action being taken
  v. Potential danger to men and/or equipment
  vi. Additional manpower and equipment required

Continued on next page

Table 4. Continued

This person shall be available to communicate details of fire and suppression action being taken and required on the fire.

c. The individual in charge of the crew shall continue to supervise fire fighting operations until company forest protection and/or Alberta Forest Service personnel arrive on site.
d. The crew will continue fire suppression operations until relieved by the company forest protection representatives or the Alberta Forest Service.
e. The person in charge of the crew shall record or designate someone to document the following information:
   i. How and where fire originated
   ii. Time of discovery
   iii. Time initial suppression action was taken
   iv. Time crew arrived on fire
   v. Log time equipment (i.e., bulldozer and fire pumps) was brought on site or set up
   vi. Time fire was brought under partial control
   vii.Time fire was being held
   viiiTime fire was out of control
   ix. Time fire escaped
f. Review "The Proposed Eight Firefighting Commandments—"WATCH OUT" and "The Present Ten Standard Firefighting Orders".
g. Assist company forest protection personnel and Alberta Forest Service as required, in planning and actioning fire suppression operations.

Table 5. Weldwood's (Hinton Division) inventory of company hand tools, fire pump equipment, and fire suppression-related camping equipment

Item	Quantity	Item	Quantity
Axes, single blade	123	Shovels	216
Axes, double blade	6	Tanks, canvas (1135.5 L)	2
Backpacks (for carrying hose)	69	Tanker, wheeled (3785 L)	1
Backpack pumps (19 L)	126	Tankers, wheeled (1892.5 L)	9
Bags, drinking (4 L)	111	Tankers, wheeled (1135.5 L)	1
Board, pack (Trapper Nelson)[a]	16	Tankers, slip-on[b]	2
Cans, gas (7.6 L)	13	Thieves, water	50
Couplings, siamese	59	Tongs, hose, laying	6
Hats, safety	23	Torches, burning	20
Hose (2.54 cm, lined)	6400 m	Wrench, hose	68
Hose (3.81 cm, lined)	945 m	Basins, hand, plastic (4.7 cm diameter)	29
Hose (3.81 cm, unlined)	1200 m		
Hose, suction	28	Blankets	603
Hose, vibrator	54	Cans, water, plastic (19 L)	31
Jerricans	25	Grinders, tools, hand	4
Lamps, head, electric	79	Kits, first aid, 50-person	22
Nozzles	71	Kits, mess, 10-person	11
Pails, metal	163	Kits, mess, 20-person	11
Pails, canvas	140	Lanterns	43
Pulaski, tools	170	Stove, wood, portable	8
Pumps, power	24	Stove, propane	2
Rakes, fire	87	Tarps, 14 × 16, canvas	120
Saws, power	7	Tarps, 8 × 10 × 3	11
Saws, Swede	54	Tents, 12 × 14 × 4	32
Stranglers, hose	57		

[a] Hose packs not included.

[b] Complete with foam units.

COMPANY FIRE ORGANIZATION

Weldwood's fire organization is designed to support and complement the AFS system. It is arranged into three categories:

1. headquarter-level organization—provides command and service functions (Fig. 2);

2. district sector-level fire organization—provides command, line, service, and plans functions (Fig. 3); and

3. division-level fire control organization—provides command and line functions (Fig. 4).

A listing of personnel and their assigned responsibilities are included in the annual FCP. These individuals and groups are aware that they may be assigned to jobs other than those under which they are listed or that they may not be involved at all, especially on smaller fires. The positions of fire boss, line boss, air operation officer, plans chief, and mix master are normally filled by AFS staff or people appointed by them.

During the 1987 and 1988 fire seasons, Weldwood Forest Protection personnel worked with the Hinton fire department and Hinton District AFS in formulating an action plan to address the local potential rural-urban interface fire problems. This plan is still in the initial stages of organization and implementation, but progress has been made in several areas. Interagency training programs have been sponsored by each agency and interface of equipment is ongoing. An interrelated command system has been developed and is working reasonably well.

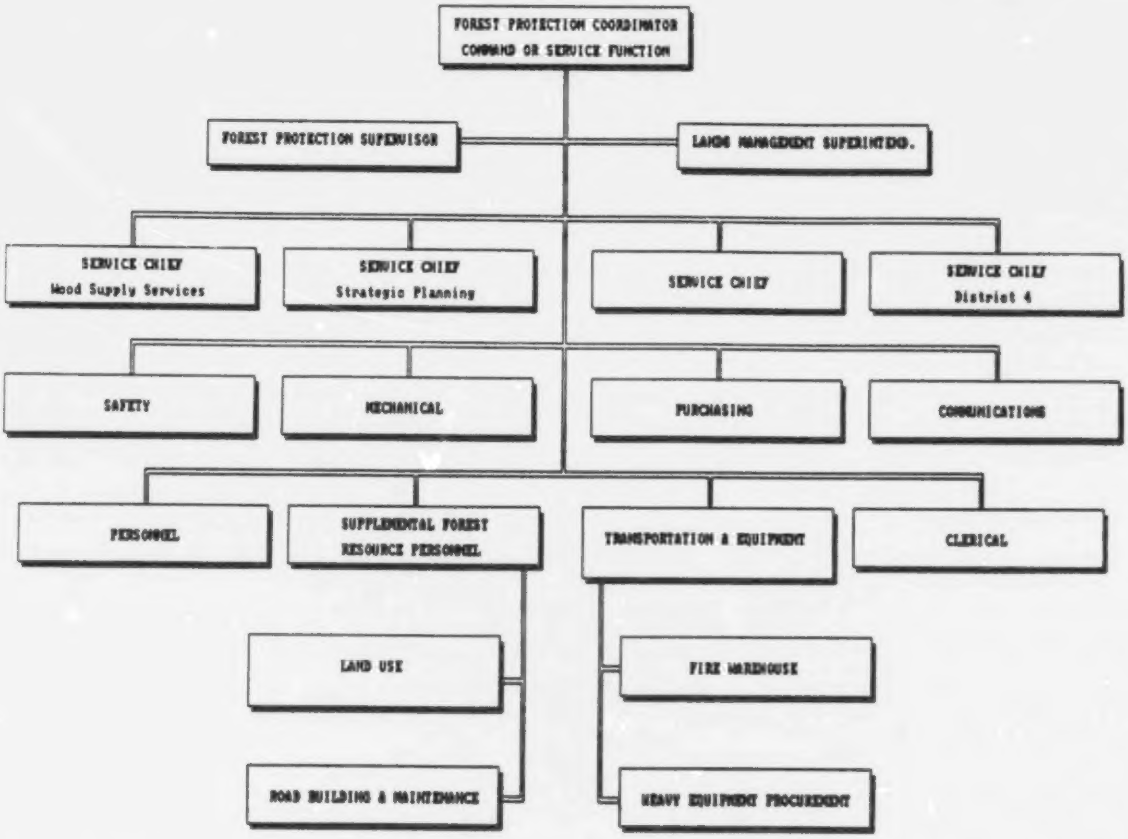
FOREST PROTECTION COORDINATOR
COMMAND OR SERVICE FUNCTION
FOREST PROTECTION SUPERVISOR
LANDS MANAGEMENT SUPERINTEND.
SERVICE CHIEF
Wood Supply Services
SERVICE CHIEF
Strategic Planning
SERVICE CHIEF
SERVICE CHIEF
District 4
SAFETY
MECHANICAL
PURCHASING
COMMUNICATIONS
PERSONNEL
SUPPLEMENTAL FOREST
RESOURCE PERSONNEL
TRANSPORTATION & EQUIPMENT
CLERICAL
LAND USE
ROAD BUILDING & MAINTENANCE
FIRE WAREHOUSE
HEAVY EQUIPMENT PROCUREMENT

Figure 2. Weldwood of Canada Limited's (Hinton Division) headquarters level organization for 1988.

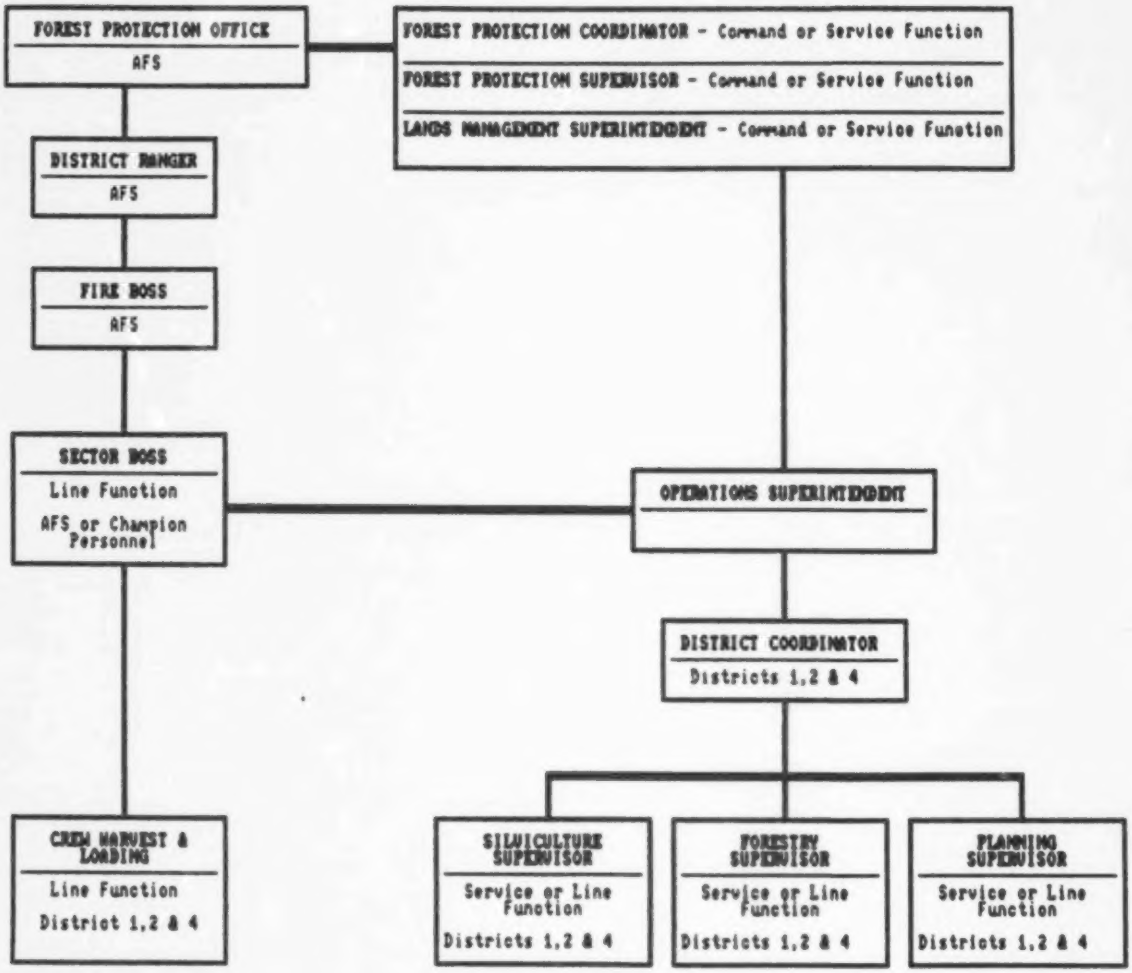
FOREST PROTECTION OFFICE
AFS
FOREST PROTECTION COORDINATOR - Command or Service Function
FOREST PROTECTION SUPERVISOR - Command or Service Function
LANDS MANAGEMENT SUPERINTENDENT - Command or Service Function
DISTRICT RANGER
AFS
FIRE BOSS
AFS
SECTOR BOSS
Line Function
AFS or Champion Personnel
OPERATIONS SUPERINTENDENT
DISTRICT COORDINATOR
Districts 1,2 & 4
CREW HARVEST & LOADING
Line Function
District 1,2 & 4
SILVICULTURE SUPERVISOR
Service or Line Function
Districts 1,2 & 4
FORESTRY SUPERVISOR
Service or Line Function
Districts 1,2 & 4
PLANNING SUPERVISOR
Service or Line Function
Districts 1,2 & 4

Figure 3. Weldwood of Canada Limited's (Hinton Division) sector level fire control organization for 1988. If the silviculture, forestry, and planning supervisors are used in the line function, they will work under the sector boss/line function organization.

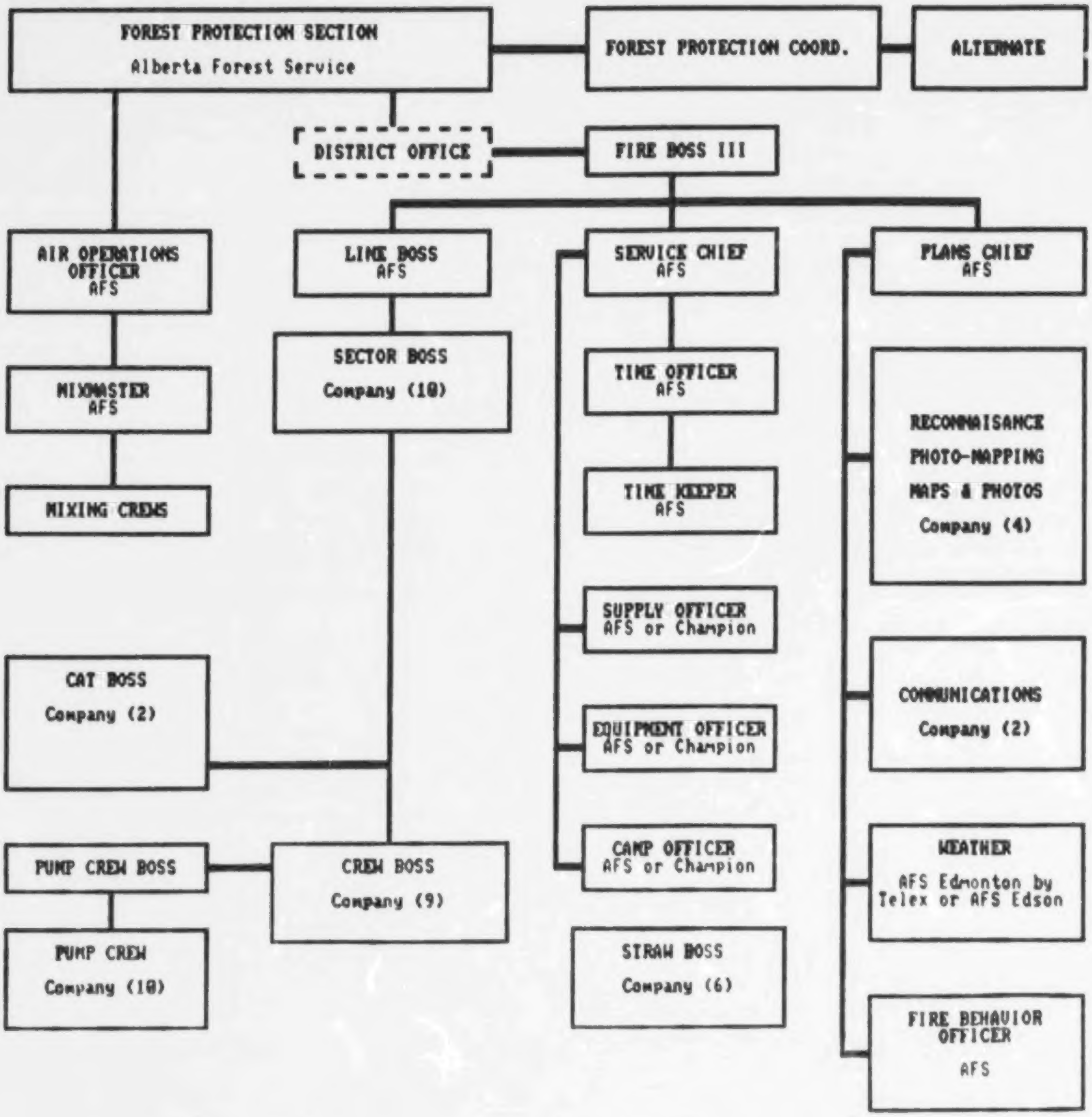
FOREST PROTECTION SECTION
Alberta Forest Service
FOREST PROTECTION COORD.
ALTERNATE
DISTRICT OFFICE
FIRE BOSS III
AIR OPERATIONS OFFICER
AFS
LINE BOSS
AFS
SERVICE CHIEF
AFS
PLANS CHIEF
AFS
MIXMASTER
AFS
SECTOR BOSS
Company (10)
TIME OFFICER
AFS
RECONNAISANCE
PHOTO-MAPPING
MAPS & PHOTOS
Company (4)
MIXING CREWS
TIME KEEPER
AFS
SUPPLY OFFICER
AFS or Champion
CAT BOSS
Company (2)
EQUIPMENT OFFICER
AFS or Champion
COMMUNICATIONS
Company (2)
PUMP CREW BOSS
CREW BOSS
Company (9)
CAMP OFFICER
AFS or Champion
WEATHER
AFS Edmonton by
Telex or AFS Edson
PUMP CREW
Company (10)
STRAW BOSS
Company (6)
FIRE BEHAVIOR OFFICER
AFS

Figure 4. Weldwood of Canada Limited's (Hinton Division) division level fire control organization command line functions for 1988.

RISK REDUCTION IN FOREST MANAGEMENT PLANNING

Forest Management Agreement operations provide an excellent opportunity to capitalize on risk reduction through wise fire and timber management planning. Dempster and Stevens (1987) state, "In areas under industrial forest management, considerable potential exists for reducing the probability of fire and other catastrophic losses at little cost. Efforts to reduce risk must be coordinated with other activities. In particular, harvest scheduling should reflect differences between locations in potential fire and pathogen behavior." Fiber losses through fire will continually occur at irregular rates in the years to come. These losses may be greatly reduced and the probability of severe fires decreased through fuel manipulation by harvesting, firebreaks, etc. Opportunities exist to reduce risk substantially with minimum reduction in annual allowable cut. As with most other investments, a cost-benefit analysis should be attempted to justify the extent of risk reduction required to achieve designated fire management goals.

MAJOR PROBLEMS EXPERIENCED BY WELDWOOD ON WILDFIRE SUPPRESSION

The major problem faced by Weldwood's involvement in fire protection is one of verbal communication with the AFS or other agencies working on fire suppression activities. On numerous fire occasions the AFS and Weldwood personnel were unable to adequately communicate with each other. Each organization is currently using different radio systems, which are incompatible. When this type of situation exists there is always a potential safety concern. Manpower and equipment efficiency are hindered, especially during critical initial attack periods when good communication is the key to safe and effective fire suppression. Weldwood is in the process of implementing a new radio system that has the potential of being linked with the AFS systems. This possibility will be explored in the near future.

WILDFIRE DE 2-20-88: AN EXAMPLE OF FOREST INDUSTRY INVOLVEMENT IN FIRE PROTECTION

On November 30, 1988, a wildfire (designated DE 2-20-88 by the AFS) spread from Gregg River Resources Ltd. mining lease onto the Weldwood FMA area. Integrated initial fire actioning included personnel from Gregg River Resources Ltd., Cardinal River Coals, the AFS, and Weldwood's Forest Protection and District 3 sections. Extreme fire conditions minimized existing suppression efforts, and by the second day all of Weldwood's Forest Resource hourly and salaried staff were actively involved with fire suppression efforts from overhead planning and service support to line functions. All hauling and harvesting operations were immediately shut down. Fire and heavy equipment ranging from company bulldozers to skidder tankers were deployed for fireline tasks. Weldwood manpower and equipment continued working as a self-contained unit under the direction of the AFS until it was evident that manning down could be safely initiated. The final size of fire DE2-20-88 was 681 ha. This wildfire exemplifies the impact and resource support potential of industry involvement in fire protection.

CONCLUSIONS

Weldwood's Hinton Division places a high priority on forest fire prevention and suppression. Expenditures in the forest protection section of the company average $700,000 annually.

The forests growing on Weldwood's one-million-hectare FMA area are the legal property of the company. Their value exceeds one billion dollars. The company is obliged and determined to protect and manage the forest resource wisely. There will always be minor problems associated with forest industry involvement in fire prevention, but many of these will be overcome with good communication and cooperation between forest companies and government agencies. Fortunately, Weldwood is now in this position.

To be effective the forest industry must keep abreast of new developments within the provincial forest protection systems. Adaptability will be required to meet changing technology and objectives.

Government forest services and municipal agencies need to take an active interest in the individual forest companies' fire prevention programs so that they may better utilize this valuable experienced resource. This will involve on-site meetings, tours of fire facilities, joint training and introduction of new personnel.

All organizations, government and industry alike, should recognize the selective use of fire as a management tool. New methods of mechanical harvesting are focusing on this economical type of treatment for slash disposal.

Risk of catastrophic destruction by fire can be reduced (but never eliminated) by innovative forest management planning translated into operational guidelines. There are ways for the forest industry to make viable contributions to forest protection, and when you look at it, it is this industry that benefits the most.

ACKNOWLEDGMENTS

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THE RURAL-WILDLAND FIRE SITUATION IN NORTH DAKOTA

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ABSTRACT

This paper gives an overview of the rural-wildland fire situation in North Dakota. The plains of North Dakota encompass over 17 million ha of cropland, rangeland, and scattered forested areas. Statewide fire suppression responsibility is entirely dependent on the suppression capabilities of the rural fire departments. An interagency state fire management organization acts as a support base for rural fire activities, providing training, technical assistance, equipment, and reinforcement when necessary. Future fire control developments, necessitated by a decreasing rural population base and changing land management practices are also discussed.

INTRODUCTION

As cooperative fire endeavors increase between states and federal wildland fire organizations, it seems appropriate and mutually beneficial for fire management personnel to become familiar with differences, variations, and similarities in one another's fire programs to facilitate coordinated efforts. This paper provides an overview of the wildland fire situation in North Dakota. It describes the grassland complex that comprises most of the state and the role that fire has played in developing and maintaining these grasslands. It presents the North Dakota wildfire organization and its dependence on volunteer rural fire departments for fire control and suppression. It addresses some of the shortcomings in the program, and provides insight into the future direction of the program.

THE FIRE ENVIRONMENT

The plains of North Dakota encompass over 17 million ha of cropland, rangeland, and scattered forested areas. Eastern North Dakota is characterized by large tracts of rich farmland that produce abundant small grain crops. This gives way to the prairies of western North Dakota, with vast areas of native grasslands and rugged badlands. The semiarid climate tends to favor a grassland ecosystem. Forested areas account for about 210 000 ha, which is less than 1% of the total land area, making North Dakota the least forested state.

Wildfire is thought to have played a key role in helping to develop the vast grassland complex found in the state, converting areas of woodlands into grasses, and maintaining existing grassland areas. The journals and narratives of early explorers, trappers, and missionaries made frequent reference to fire occurrences (Higgins 1986). Many fires were attributed to Indian activities and were set for communication and signaling purposes, warfare, and as a tool to aid in hunting and herding animals. Lightning-ignited fires, though probably more infrequent, may have been responsible for fires of great magnitude that caused repeated burning of open grasslands.

Devastating prairie fires were also a common threat to early settlers in the state. An early 1900s newspaper report told of prairie fires burning in every direction from the state capital in Bismarck (*Bismarck Tribune*, March 24, 1910), and in 1926 a prairie fire reportedly burned 40 000 ha in western North Dakota, consuming over 8000 ha in less than 4 hours (*Bismarck Tribune*, Oct. 15, 1926). The incidence of wildfire conflagrations eventually decreased as grasslands were segmented by roads and replaced by cultivated croplands and as small rural communities established fire departments and organized fire districts.

THE FIRE MANAGEMENT ORGANIZATION

With a widely dispersed, primarily rural population, North Dakota continues to rely entirely on over 300 rural volunteer fire departments across the state for fire control and suppression. Over the years the rural fire departments have been extremely successful in suppressing wildfires, with fires in excess of 400 ha accounting for a very small portion of total acres burned. In a 10-year period from 1976 to 1986, fire statistics show an average annual fire occurrence of about 450 fires, burning 4000-6000 ha.

A North Dakota wildfire protection plan was formulated in 1981 to facilitate the working relationship between state emergency fire personnel and rural fire departments. This plan provides for establishing a state wildfire organization, consisting of the North Dakota Division of Emergency Management, State Fire Marshal's Office, North Dakota Fireman's Association, U.S. Forest Service, and the North Dakota Forest Service (NDFS). It evaluates wildfire conditions, establishes and implements fire mitigation measures, monitors wildfire protection services, and provides assistance to rural fire departments in the event of a major fire incident.

The NDFS was given the lead role in providing wildfire program assistance to rural communities. The NDFS administers two federal wildland fire programs to assist rural fire departments in obtaining equipment and training. The Rural Community Fire Protection Program (RCFP) provides cost-shared funds to help with training and purchasing fire equipment. Since 1975 more than 1.2 million dollars has been distributed to rural fire departments across the state. The Federal Excess Personal Property Program (FEPP) loans excess federal equipment and vehicles to rural fire departments (Russ 1987). The NDFS obtains, allocates, and provides assistance in helping rural fire departments modify and renovate the vehicles for fire use. Currently over 200 fire-fighting vehicles are on loan to rural fire organizations. The NDFS also participates in conducting regional wildfire training courses for rural fire fighters and is currently developing a central fire cache for statewide fire equipment distribution to further assist rural fire organizations.

In 1988 North Dakota experienced an unusually severe fire season. Drought conditions from the previous fall, an unusually mild winter, a lack of precipitation until late summer, and hot, dry weather created critical burning conditions in early spring that continued through the summer. Over 950 fires were reported in the state, burning an estimated 120 000 acres. Rural fire departments requested state assistance on five large wildfires. On three occasions, the state provided assistance to federal fire overhead teams brought fire fighters in from across the nation to fight wildfires on the Little Missouri National Grasslands. State fire personnel helped to coordinate the local suppression efforts with federal efforts. National Guard helicopters were used to make water drops and fly reconnaissance, and state crews were assembled to help with extended attack and mop-up operations.

PROGRAM DEVELOPMENT

The 1988 fire season helped to identify a number of shortcomings that existed in the state wildfire program, and steps are being taken to improve the situation. Fire contingency plans are being updated and will provide for more direct state involvement on large fires. Renewed emphasis is being placed on wildfire training for rural fire departments, and the Incident Command System is being introduced to provide for extended attack operations on large fires. Across the state, commercial crop sprayers are being contracted and trained to provide air attack on grassland fires.

Other long-term developments that may have an affect on the wildfire protection program involve declining rural populations and changing land-management practices. The Conservation Reserve Program (CRP) is a federal farm program that encourages farmers to take marginal croplands out of production and plant them to grass or trees. Over 800 000 ha are enrolled so far in the state, with several counties having up to one-third of the land area converted to CRP grasslands. In some areas small rural communities are totally surrounded by CRP lands, creating North Dakota's version of the urban-wildland interface problem. A continued decline in North Dakota's rural population also poses problems. Rural fire departments are experiencing hardships in providing adequate fire protection in some areas due to manpower shortages and lack of an adequate tax base. Rural fire departments are looking to the state for assistance in dealing with these situations.

CONCLUSIONS

With periods of extended drought, hot and windy weather conditions, and an abundance of flash fuels, the potential for optimum burning conditions for wildfire in North Dakota occurs fairly frequently. Through the years, rural fire departments and the state wildfire protection program have proven very successful in their fire control efforts; however, the 1988 fire season showed a need for increased effort in dealing with large scale fire situations. North Dakota recognizes the value of developing close working relationships, sharing information, and sharing resources with all types of fire organizations on the local, state, and national levels, in seeking to achieve efficient, optimal fire protection.

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PRESCRIBED FIRE PRACTICES IN THE INTERIOR WEST: A SURVEY

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ABSTRACT

Information on prescribed fire practices within the Interior West Fire Council area are obtainable from a variety of U.S. and Canadian sources for the 1987 and 1988 burning seasons. The difficulty of obtaining prescribed fire records and the lack of comparability of available records precludes a comprehensive presentation of prescribed fire use and practices. To the extent possible, 1987 prescribed fire activity is compared to a past level of burning. Several innovative prescribed fire programs are highlighted to indicate possible future directions of prescribed burning in the Interior West. As a general rule, prescribed fire activity has increased throughout the region. Most of the increase is related to burning for vegetation management objectives rather than fuel hazard reduction. A standard prescribed fire reporting format is suggested to facilitate future surveys.

INTRODUCTION

Prescribed burning is a popular forest and rangeland management practice throughout the Interior West geographical region of the United States and adjoining Canadian provinces. It is often the preferred treatment for reducing fuel hazard, preparing sites for seeding and planting, and manipulating vegetation, especially for range and wildlife habitat management. This paper assesses the current status of fire use within the membership area of the Interior West Fire Council (IWFC).

Although we intended to present a comprehensive survey of current prescribed fire practices within the Interior West, we soon discovered that such a task was unrealistic. Three major obstacles thwarted the comprehensive approach: 1) the size of the region that encompasses the nine American states and two Canadian jurisdictions, 2) the large number of federal, state, and private entities engaged in prescribed burning within the region, and 3) the absence of complete and comparable records from which fire-use statistics could be compiled. We were able, however, to obtain sufficient information to reflect current trends. Information sources included fire-use records for the U.S. national forests and the public grazing lands within the IWFC area, a Canadian prescribed fire survey, other written reports of prescribed fire activities within the area, and discussions with agency fire managers and resource specialists. Several innovative prescribed fire programs are described to indicate the possible future course of fire use in the region. We suggest a prescribed fire reporting procedure to facilitate future attempts at summarizing prescribed fire practices in the Interior West.

PRESCRIBED FIRE IN U.S. NATIONAL FORESTS

The Northern Region

The Northern Region (R-1) of the U.S. Department of Agriculture (USDA) Forest Service maintains records of prescribed fire accomplishments for the national forests and national grasslands of northern Idaho (north of the Salmon River), Montana, North Dakota, and northwestern South Dakota. These records are included in R-1's computerized Timber Stand Management Reporting System (TSMRS) and are the most complete prescribed fire records we found in the Interior West. The TSMRS provides 31 fuel-treatment activity codes, the following 15 of which are related to fire:

- Ecosystem burning (grassland)
- Ecosystem burning (shrubland)
- Ecosystem burning (stand modification)
- Burn piles (dozer)
- Burn piles (hand)

- Burn piles (grapple)
- Broadcast burn
- Jackpot burn
- Understory burn
- Wildfire
- Wildlife burn
- Unplanned ignition prescribed fire
- Burning for range improvement
- Shrubland burning (hazard reduction)
- Burn landings

We used information from the TSMRS to compile the following R-1 prescribed fire accomplishments for 1987 and those proposed for 1988 (Table 1). In 1987, 32 555 ha of R-1 national forest lands were treated by manager-ignited prescribed fire. This total reflects an 81% increase over the 1979 prescribed burned hectarage reported for the Northern Region by Noste and Brown (1981). Although this increase appears to be significant, it could reflect either a poor burning year in 1979 or a good burning year in 1987, or both. Of greater significance than the increase in total hectares burned is the relative change in the number of hectares burned by management objective. In 1979, 97% of the hectares burned in R-1 involved treatment of logging slash for the purpose of either hazard reduction or site preparation or both. In 1987, slash burning accounted for 67% of the hectares burned (a 26% increase from 1979), and burning in natural fuels for range and wildlife habitat improvement and multiresource objectives accounted for 33% of the hectares burned (an increase of 18 times that in 1979). The current trends of increasing numbers of hectares treated by fire and increasing use of fire in natural fuels is reinforced by the Northern Region's prescribed fire plans for 1988.

Ecosystem Maintenance Burning in Lolo National Forest, Montana

The Northern Region's Lolo National Forest has developed an integrated approach to the application of fire in a systematic manner both to achieve commodity outputs and to maintain a stable vegetative community[1]. This strategy for Ecosystem Maintenance Burning (EMB) is designed to support the concept of ecosystem stability that has been incorporated into the management of the Lolo National Forest through its Forest Plan. Ecosystem stability is defined as a physiographic replication of the age structure and vegetative composition as found under near natural conditions[2]. In forest management, maintenance of a stable ecosystem is important for ease of management and prevention of major community perturbations (caused by wildfire, insects, disease, windthrow, etc.) that may result in loss of cover for wildlife. An assessment of fire effects on ecosystems within the Lolo National Forest concluded that ecosystem stability cannot be maintained by traditional fire exclusion practices. Conversely, ecosystem stability in fire-

Table 1. Past, present, and anticipated prescribed fire accomplishments on USDA Forest Service Northern Region (R-1) lands

Management objective	Area (ha) 1979	1987	1988 (proposed)
Hazard reduction			
Pile	13 749	12 083	15 702
Landing	700	454	691
Site preparation	3 028	9 503	15 267
Forest and range improvement			
Wildlife	163	4 905	3 422
Range	391	5 487	4 953
Ecosystem	0	125	1 753
Totals	18 031	32 555	41 788

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[1] Losensky, J.; Applegate, V.; Deibert, J.; Barndt, S.; Williams, J.; Berglund, D. 1987. A strategy to implement ecosystem maintenance burning on the Lolo National Forest. U.S. Dep. Agric., For. Serv., Lolo Natl. For., Missoula, Montana. Unpubl. rep.

[2] Losensky, J.; Applegate, V.; Deibert, J.; Barndt, S.; Williams, J.; Berglund, D. 1987. A strategy to implement ecosystem maintenance burning on the Lolo National Forest. U.S. Dep. Agric., For. Serv., Lolo Natl. For., Missoula, Montana. Unpubl. rep.

dependent systems of the Lolo National Forest can be typically achieved with maintenance prescribed burning in the form of regularly scheduled application of prescribed fire resulting from either planned or unplanned ignition. Where the effects of long-term wildfire suppression preclude a first entry with prescribed fire, alternative treatment may precede maintenance burning. Alternative treatment may also be required in other areas where resource considerations or management constraints limit or altogether preclude regularly scheduled prescribed fire.

Planned implementation of EMB is based on a thorough interdisciplinary evaluation of Lolo National Forest ecosystems including habitat types, vegetal composition, site, stand, and fuel characteristics, fire ecology and expected fire effects, fire frequency, management goals, economic and budgeting considerations, potential treatment effectiveness, and treatment priority. Full implementation of the EMB program requires the treatment of nearly 4856 ha annually. Budget constraints, workforce limitations, and scarcity of favorable burning conditions preclude optimum implementation. Consequently, current implementation is incremental with about 461 ha of Priority 1 lands treated annually along with as many of the 820 ha of Priority 2 lands as budget and operational constraints allow.

The Rocky Mountain Region

The Rocky Mountain Region (R-2) of the USDA Forest Service maintains prescribed fire records for the national forests and national grasslands of Colorado, Nebraska, southern South Dakota, and for portions of Wyoming lying east of the Continental Divide. Records of prescribed fire accomplishment in the recent past are not readily available, but we were able to obtain the estimates[3] given in Table 2.

Records of 1987 prescribed fire accomplishments for all but three R-2 national forest units are given in the newsletter *Burning Issues for Resource Managers in the Rocky Mountain West* (Colorado State Forest Service 1988) prepared by an interagency prescribed fire working group. Member agencies of this group include the Colorado State Forest Service, Colorado Division of Wildlife, USDA Forest Service, U.S. Department of the Interior (USDI) Bureau of Land Management, USDI National Park Service, and USDI Fish and Wildlife Service. The records, although incomplete, indicate the substance and direction of the current R-2 prescribed fire program (Table 3). Areas treated with prescribed fire for slash hazard reduction and other timber management related burning (in ponderosa pine) would be greater if Black Hills National Forest accomplishments were included in the above figures. A large portion of the unspecified hectarage on the Grand Mesa, Uncompahgre, and Gunnison national forests involves burning in standing lodgepole pine to control dwarf mistletoe and improve bighorn sheep habitat. As indicated in Table 4, R-2 national forests and national grasslands plan to burn an estimated 24 356 ha during 1988. Planned accomplishment by management objective is given in Table 4. As in the 1987 compilation, much of the unspecified hectarage is on the Grand Mesa, Uncompahgre, and Gunnison national forests and involves burning lodgepole pine for silvicultural and wildlife purposes.

Burning Lodgepole Pine Stands in Gunnison National Forest, Colorado

Personnel on the Taylor Ranger District of the Gunnison National Forest have implemented an innovative program of large-scale prescribed burning in high elevation old growth spruce-fir and dwarf mistletoe-infested lodgepole pine stands[4]. This program evolved from mistletoe control burns in relatively small stands (about 12 ha) of heavily infested lodgepole pine that in some instances were partially laid on the ground but in other instances were left standing undisturbed. Management objectives for these mistletoe control burns were hazard reduction, site preparation, and lodgepole pine mortality. The following are corresponding fire objectives.

1. Reduce the dead and down roundwood fuel component as follows:

Diameter size class (cm)	Time lag (h)	Reduction (%)
0-0.64	1	90
0.64-2.54	10	75
2.54-7.62	100	50
7.62 +	1000	15

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[3] A. Roberts, Staff Assistant, Fuels Management, U.S. Dep. Agric., For. Serv., Rocky Mt. Region, Air, Aviation and Fire Management, Lakewood, Colorado, personal communication.

[4] Chonka, G.E. 1986. Red Mountain mistletoe control prescribed burn plan. U.S. Dep. Agric., For. Serv., Grand Mesa, Uncompahgre, and Gunnison Natl. For., Taylor Ranger Dist., Gunnison, Colorado. Unpubl. Rep.

Table 2. Past, present, and anticipated prescribed fire accomplishments on USDA Forest Service Rocky Mountain Region (R-2) lands

Year	Area (ha)
1979	1 619
1985	6 880
1987	9 713
1988 (proposed)	24 282

Table 3. Prescribed fire accomplishments on USDA Forest Service Rocky Mountain Region (R-2) lands during the 1987 burning season

Management objective	Fuel type	Area (ha)
Wildlife habitat improvement	Sagebrush	182
	Aspen	61
	Oakbrush and aspen	225
	Oakbrush	1329
	Sagebrush and chained pinyon-jumper	162
	Oakbrush and sagebrush	726
Total wildlife	All of the above	2685
Range improvement	Sagebrush	162
Timber stand improvement	Oakbrush under ponderosa pine	142
Slash hazard reduction	Lodgepole pine	128
Unspecified[a]	Unknown	6475

[a] Includes the Grand Mesa, Uncompahgre, and Gunnison national forests.

Table 4. Planned prescribed fire accomplishments on USDA Forest Service Rocky Mountain Region (R-2) lands during the 1988 burning season

Management objective	Areas (ha)
Fuel treatment	3 869
Silviculture/timber management	1 238
Recreation	17
Range improvement	2 365
Wildlife habitat	9 988
Unspecified	6 880
Total	24 356

2. Eliminate duff layer on 50% of burned area.

3. Kill 97% of mistletoe-infested lodgepole pine seedlings and saplings.

Key prescription elements that resulted in successful accomplishment of the above objectives included ignition at night, an ignition probability of 40% or less, and predicted spotting distance of less than 80 m.

Experience and confidence gained in mistletoe control burns provided the basis for the more ambitious bighorn sheep habitat improvement prescribed fire program. The management objectives for this program are 1) to create new and enhance existing summer range, 2) open up traditional and create new migration routes to reduce stress levels in bighorn sheep, and 3) reduce snail populations that contribute to the propagation of lungworm in bighorn sheep[5]. The Gandy Gulch prescribed fire project illustrates the nature of burning for bighorn sheep on the Taylor Ranger District[6]. The Gandy Gulch project involves 5256 ha at elevations between 2749 and 3658 m mean sea level (MSL) with slopes of 0-120%. The project area includes 3370 ha targeted for burning and 1887 ha of land nontargeted for burning. Target areas include 2761 ha of primary lands and 608 ha of secondary lands. Primary lands are hand ignited and allowed to burn with no control action. Secondary lands are ignited due to spotting or by spread from the primary lands. Fires in secondary lands are allowed to burn with minimal action as defined in a contingency plan. Ignitions from spotting or spread from target areas into nontarget areas are suppressed. Cover types in the primary area are Douglas-fir (5%), spruce-fir (20%), grass and mixed conifer and grass (28%), aspen (5%), and lodgepole pine (42%) with heavy-to-moderate mistletoe infestation. Corresponding BEHAVE fuel models (Andrews 1986) are as follows: 1 (short grass), 2 (timber, grass, and understory), 8 (closed timber litter), and 10 (timber, litter, and understory). Desired fire accomplishment to meet management objectives is as follows:

Fuel model	Fire objective
1	Burn at least 70% of total area, killing at least 60% of the conifers.
2	Burn at least 70% of total area, killing at least 50% of the conifers.
8	Burn at least 20% of total area, killing at least 95% of the conifers.
10	Burn at least 60% of total area, killing at least 60% of the conifers.

Prescription elements developed to accomplish the above objectives and to minimize escape, damage to site productivity, and adverse air quality include 1) ignition probability of 70% or less; 2) spotting distance of 0.64 km or less; 3) minimum flame lengths of 45 cm for Fuel Model 1, 75 cm for Fuel Model 2, 30 cm for Fuel Model 8, and 90 cm for Fuel Model 10; and 4) National Fire Danger Rating System Manning Class of 4 or less, and good or better smoke dispersal conditions. Monitoring and evaluation on 773 ha indicates that all fuel model related objectives were accomplished.

The Intermountain Region

The Intermountain Region (R-4) of the USDA Forest Service, maintains records of prescribed fire for national forests in Nevada, Utah, western Wyoming (west of the Continental Divide), and southern Idaho (south of the Salmon River). Prescribed fire accomplishments during the 1987 fire season are summarized[7] in Table 5. These figures include accomplishments on 12 of the 16 national forests in R-4. Evidently, no prescribed fire activity occurred on the Caribou, Salmon, Toiyabe, and Wasatch-Cache national forests during 1987. Hazard reduction burning during 1987 involved 228 ha of piles and planned ignition on 101 ha of rangeland and 502 ha of timberland. The wildlife improvement burning was conducted on 123 ha of timberland and 866 ha of rangeland. Wildlife improvement and range improvement

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[5] Chonka, G.E. 1986. Wildlife habitat improvement, bighorn sheep, Gandy Gulch prescribed burning plan. U.S. Dep. Agric., For. Serv., Grand Mesa, Uncompahgre, and Gunnison Natl. For., Taylor Ranger Dist., Gunnison, Colorado. Unpubl. Rep.

[6] Chonka, G.E. 1988. Burning in lodgepole pine stands to improve habitat for bighorn sheep, to eradicate dwarf mistletoe, and for other purposes: a west-central Colorado case study. Unpublished lesson plan prepared for Fire Prescription Writing Training Course, April 12-14, 1988, Boise, Idaho. U.S. Dep. Inter., Bureau Land Manage., Boise Interagency Fire Cent., Boise, Idaho.

[7] Beddow, T., Regional Fuels Management Officer, U.S. Dep. Agric., For. Serv., Intermt. Reg., Aviation and Fire Management, Ogden, Utah. Personal communication.

Table 5. Prescribed fire accomplishments on USDA Forest Intermountain Region (R-4) lands during the 1987 burning season

Management objective	Area (ha)
Hazard reduction	831
Site preparation	61
Wildlife improvement	990
Range improvement	1404
Unspecified	405
Total	3690

burning accounted for 65% of the total R-4 prescribed fired accomplishment for 1987, whereas hazard reduction burning accounted for 22%. We were unable to obtain reliable estimates of R-4 prescribed fire plans for 1988, but based on discussions at the region's 1987 fire and silviculture workshop (Hamilton 1988), a dramatic increase in fire use is planned, especially for timber stand, range, and wildlife habitat improvement purposes.

PRESCRIBED FIRE ON U.S. PUBLIC LANDS

The public lands are those U.S. federal wildlands not designated as national forest, national park, national monument, or national wildlife refuge areas and are managed by the Bureau of Land Management (BLM) of the U.S. Department of the Interior). Traditionally, management emphasis on these lands was for livestock grazing but is now multiple-use oriented. During the present decade, prescribed fire accomplishment on all public lands administered by the BLM has remained relatively constant. Total area treated (Table 6) has varied between 28 677 and 44 782 ha since 1980. Prescribed fire accomplishments on BLM lands within the Interior West Fire Council membership area for the fiscal year of 1987 are presented[8] in Table 7. According to Ferry, the role and use of fire on BLM land is changing. New fire management policies, emphasis on the recognition of fire as a generic responsibility of all vegetation managers, new operational technologies and a new fire management planning process is greatly affecting the traditional views of fire suppression and fire use[9].

PRESCRIBED FIRE IN THE STATE OF COLORADO

Information contained in the previously mentioned newsletter, *Burning Issues* (Colorado State Forest Service 1988) provides the basis for assessing prescribed fire use within the boundaries of a single western U.S. state, in this case, Colorado. The compilation presented in Table 8 shows Colorado's 1988 individual and combined planned prescribed fire accomplishment by the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and the Colorado State Forest Service (CSFS). The area assigned to the forestry-wildlife management objective in Table 8 includes the 6880 ha of unspecified lands on the Grand Mesa, Uncompahgre, and Gunnison national forests identified in our previous discussion of prescribed fire in the Rocky Mountain Region. The areas assigned to the recreation objective are State of Colorado recreation lands planned for burning to reduce noxious weeds.

Considering the above numbers involved in the Colorado compilation, we find that 37% of the planned burning involves (in whole or in part) a forestry related objective, 28% involves a range objective, and 64% involves a wildlife objective. These figures represent an ambitious burning program for Colorado. To provide perspective, Sandberg et al. (1979) indicate 1214 ha as the average annual area burned by prescribed fire in Colorado during some period prior to 1979. Even if only half of the 1988 planned burning is actually accomplished, it would represent more than a 10-fold increase over prescribed fire accomplishments in the 1970s.

PRESCRIBED FIRE IN THE PROVINCE OF ALBERTA

We were unable to easily obtain information on lands treated with prescribed fire in Alberta or the Northwest Territories, the Canadian regions included in the IWFC membership area. We were able,

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[8] Ferry, G.W. 1988. The role and use of fire on BLM lands. Unpublished lesson plan prepared for Fire Effects on Public Lands Workshop, March 7-11, 1988, Boise, Idaho. U.S. Dep. Inter., Bureau Land Manage., Div. Fire Aviat. Manage., Washington, D.C.

[9] Ferry, G.W. 1988. The role and use of fire on BLM lands. Unpublished lesson plan prepared for Fire Effects on Public Lands Workshop, March 7-11, 1988, Boise, Idaho. U.S. Dep. Inter., Bureau Land Manage., Div. Fire Aviat. Manage., Washington, D.C.

Table 6. Past prescribed fire accomplishments on all USDI Bureau of Land Management lands

Year	No. projects	Area (ha)
1980	533	32 954
1981	523	30 548
1982	520	28 677
1983	503	32 189
1984	647	44 782
1985	716	35 647
1986	715	31 673
1987	728	41 180
Average	610	34 706

Table 7. Prescribed fire accomplishments on USDI Bureau of Land Management lands in the Interior West U.S. during the 1987 burning season

State	No. projects	Areas (ha)
Colorado	31	3 900
Idaho	28	8 538
Montana	11	289
Utah	8	1 466
Wyoming	21	3 913

Table 8. Planned prescribed fire accomplishments on all state and federal lands in Colorado by agency during the 1988 burning season

	Area (ha)			
Management objective	CSFS	BLM	USFS	State-wide
Forestry	115	650	2 850	3 615
Forestry and wildlife	—	—	7 009	7 009
Wildlife	832	2 163	7 385	10 379
Wildlife and range	—	728	435	1 164
Range	486	5 376	741	6 602
Range and forestry	—	162	—	162
Recreation	71	—	—	71
Total	1 504	9 079	18 420	29 002

Table 9. Current percentage of total prescribed fire use in western Canada[a]

Management objective	Alberta[b]	National parks
Hazard reduction	28.1	36.4
Site treatment	25.0	9.1
Insect and disease control	9.4	—
Wildlife enhancement	25.0	36.4
Rangeland burning	12.5	9.1
Training	—	9.1

[a] Adapted from: McAlpine, R.S. 1986. Northern and western region prescribed fire survey results. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Study NOR-5-06. File Rep. 1.

[b] Excluding national parks.

however, to locate information on management objectives for using prescribed fire in Alberta (Table 9). The information presented in Table 9 is based on survey responses of representatives from the private sector and provincial parks, and from provincial foresters, fish and wildlife officials, forest protection officers, and department heads in Alberta. Prescribed fire objectives for national parks in western and northern Canada were reported separately (Table 9). During a recent meeting of the Canadian Forestry Service Prescribed Fire Working Group, it was reported that interest and activity in prescribed fire is increasing in Alberta both for silvicultural and wildlife applications[10].

SUMMARY OF PRESCRIBED FIRE USE IN THE INTERIOR WEST

Our evidence shows that the use of prescribed fire in the Interior West has steadily increased during the past decade compared to the previous decade. This increase is mostly due to a significant increase in prescribed burning for wildlife enhancement and other vegetation management objectives. The use of fire for slash disposal associated with timber harvest has not increased significantly on an area basis. Agency plans indicate even greater use of fire in the immediate future. Planned multi-resource and ecosystem maintenance burning programs reflect a major shift in prescribed fire practices in the Interior West during the next decade. Recall, however, that the present survey deals primarily with traditional manager-ignited prescribed fire on lands other than national parks, national forest wilderness areas, and national wildlife refuges. Prescribed fire programs involving both natural and planned ignitions in these special-use areas result in significant increases in the total area treated with prescribed fire annually.

A PROPOSED FORMAT AND PROCEDURE FOR REPORTING FIRE USE

Future compilation and reporting of prescribed fire accomplishment by member agencies of the Interior West Fire Council would be facilitated if they would summarize such accomplishments using the following, or similar, format:

Format and procedure for reporting fire use

	Area treated (ha)				
Management objective	Grassland	Shrubland	Woodland	Forest	Total
Fuel reduction					
Pile and burn					
Jackpot burn					
Broadcast burn					
Understory burn					
Site preparation					
Pile and burn					
Jackpot burn					
Broadcast burn					
Understory burn					
Wildlife enhancement					
Broadcast burn					
Understory burn					
Range improvement					
Broadcast burn					
Understory burn					
Burn single trees					

Continued on next page

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[10] Hawkes, B.C., Fire Research Officer, Forestry Canada, Pacific Forestry Centre, Victoria, British Columbia. Personal communication.

Format and procedure for reporting fire use continued

- Insect and disease control
  - Broadcast burn
  - Understory burn
  - Pile and burn

- Ecosystem maintenance

  - Manager ignition
    - Parks
    - Refuges
    - Wilderness areas
    - General use areas

  - Natural ignition
    - Parks
    - Refuges
    - Wilderness areas
    - General use areas

- Grand totals

Additional management objectives could be added to this format as deemed necessary. For example, burning done for both range and wildlife could be reported under an objective entitled Range and wildlife.

We propose that the Interior West Fire Council solicit agency participation in an annual prescribed fire reporting procedure. The procedure would require that agencies use the above format to summarize previous calendar year prescribed fire accomplishments for presentation at the council's annual meeting and distribution to members in the meeting's proceedings or as a separate report if proceedings are not published. In addition to obtaining agency participation, the council would need to designate an individual, annually or for a longer term, to gather the reports and prepare them for presentation and publication. Adoption of the proposed procedure would represent a significant service to the wildland fire community of the Interior West.

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EMERGING ISSUES AND CONCERNS ABOUT WILDLAND FIRE-FIGHTER SAFETY[1]

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ABSTRACT

This paper gives a brief review of the National Wildfire Coordinating Group's (NWCG) 1980 preliminary report on fatal and near-fatal wildland fire accidents and the recent efforts of the NWCG Fireline Safety Committee. It covers the minimum training and personal protective equipment each fire fighter should receive, the benefits of the fire shelter, and several successful deployments. Improvements in transportation and methods of reducing transportation needs of fire fighter are reviewed. Observations of the safety hazards affecting the fire fighter with the wildland-urban interface is touched on. This presentation also includes a discussion on the importance of both the physical and mental condition of the fire fighter. The paper concludes with actions each of us may consider to improve the safety and heath of our most valuable resource—our fire fighters!

INTRODUCTION

On August 29, 1985, 73 fire fighters were forced into safety zones, where they took refuge in their shelters for 1-2 hours while a very severe crown fire burned over them (Rothermel and Mutch 1986). Five fire fighters were hospitalized overnight for heat exhaustion, smoke inhalation, and dehydration. The other escaped uninjured.

In August of 1986, a 4.5-tonne dump truck left the road and rolled down an embankment. On board were two drivers, a crew of fire fighters, and a crew representative. As a result of this accident four crew members were killed and 17 others were hospitalized.

In 1987, five fire fighters responded to a fire involving a house trailer. The fire fighters quickly controlled the advance of the fire and returned to their home unit. The next day three of the five were rushed to the local hospital suffering from stomach cramps, vomiting, and headaches. All required immediate medical care and one remained hospitalized. According to the diagnosis, their condition was brought on by the inhalation of toxic fumes from the trailer fire the previous day.

Then in late August 1988, at approximately 10:00 p.m., 23 fire fighters were forced into a less-timbered area where they took protection in their fire shelters. Approximately 2 hours later five other fire fighters took refuge on a road for precautionary reasons. Four of the 23 visited the local hospital the following morning for smoke inhalation, one minor burn, and dehydration; the others were uninjured. All fire fighters and the overhead team involved with the deployment incident attended a critical incident stress debriefing within the next 48 hours.

You may be wondering why I have described these accidents and incidents, when the title of my presentation relates to wildland fire-fighter safety. One would think that only two of these incidents relates directly to fire fighting. But interestingly, all of the fire fighters involved were wildland fire fighters participating to the best of their abilities in wildland fire fighting missions.

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[1] This presentation was supplemented with three videotapes shown twice during the annual meeting and workshop entitled *Butte Fire Shelter Deployment* (33 min), *Your Fire Shelter* (19 min), and *Crank Fire Burnover* (60 min), which are available through the Publications Management System at the Boise Interagency Fire Center, Boise, Idaho.

NATIONAL DEVELOPMENTS

The National Wildfire Coordination Group (NWCG) issued in 1980 a task force report on fatal and near-fatal wildland accidents. The report was assembled by a group of fire professionals and is an in-depth study of the fire fatalities and near-misses between 1926 and 1979 in various groups. It shows some similarities between the incidents, identifies problems, and gives recommendations. Many of the recommendations were followed, and some changes occurred. Wilson's (1977) earlier study is included in the NWCG report.

Major interagency efforts to track fatalities and near-misses were somewhat discontinued on a national basis after this task force report until December of 1986, when NWCG approved and established a Fireline Safety Committee. This committee was organized to work on a number of projects designed to provide safer fireline conditions for the nation's forest and wildland fire fighters. The three-member committee was selected by NWCG with representatives from the USDA Forest Service, Department of the Interior and state forestry agencies. Their mission includes the development of a standardized, consistent approach to the collection, analysis, and distribution of information relating to facilities, major fire-related injuries and life threatening "near miss" incidents occurring in forest-wildland fire operations.

The primary objectives of the committee are as follows:

- to provide recommendations for uniform reporting of accident information;
- to review reports of major accidents;
- to identify needed emphasis among the wildfire agencies concerning fire management policy, program direction, or training in order to improve fire fighter safety;
- to develop a detailed, structured process of documentation of critical incidents to gain the maximum training benefits; and
- to initiate specific recommendations for publications, posters, visuals, or other fireline safety materials under NWCG sponsorship.

Neither the reports nor the committee can prevent fire accidents without your cooperation. All of us on the ground actually doing the fire suppression, management and support jobs have an active role in improving the safety of our fire fighters.

RECENT FATALITIES

In a meeting with the National Fire Protection Association (NFPA) and as reported in the June 1988 issue of *Fire Command*, fire protection agencies suffered 17 wildland-related fire-fighter fatalities during the 1987 fire season, resulting primarily from aircraft, tree falling, vehicle, heart failure, and entrapment accidents. This represents 32% of the 53 urban and wildland fire fatalities that occurred nationally. The NWCG Fireline Safety Committee reports indicate that 10 fatalities (one vehicle, one burn, two falling trees, six associated with aircraft) have occurred in 1988. These records have not yet been confirmed with NFPA.

Minimum training standards have been established and accepted by the wildland fire-fighting agencies. Each fire fighter should receive this recommended training prior to going to a fire. The courses are S-130 fire-fighter training, (20-30 hours) and S-190 introduction to fire behavior. These courses will give the beginning fire fighter the very basics for wildland fire fighting.

One of the newest training courses, developed by an interagency group, is "Standards for survival," an interactive video course on fire-fighter safety (Morse and Monesmith 1987; Monesmith 1988). The principal focus of this fire-fighter safety course is on the proper recognition of the "watch out" situations followed by the initiation of appropriate actions as defined in the standard fire orders (Tables 1 and 2). Five items have been added to the "watch out" situations. The standard fire orders have been recast in acrostic format to trigger recall. This new format places "fight fire aggressively, but provide for safety first" as the first order. Eight scenarios are utilized to pinpoint critical fireline events. The course is available through NWCG's Publication Management System at the Boise Interagency Fire Center, Boise, Idaho.

PERSONAL PROTECTIVE EQUIPMENT

The safety equipment required of each fire fighter is standardized. It consists of Nomex pants and shirt, hard hat with chin strap, goggles, ear plugs, 8-cm lace-up boots, gloves, and a fire shelter. There is some policy difference regarding Nomex pants. All items except the 8-cm lace-up boots are supplied by the agencies. In isolated cases, the fire fighters may have to purchase their own items.

Table 1. "Watch out!" situations

1. Fire not scouted and sized up.
2. In country not seen in daylight.
3. Safety zones and escape routes not identified.
4. Unfamiliar with weather and local factors influencing fire behavior.
5. Uninformed on strategy, tactics, and hazards.
6. Instructions and assignments not clear.
7. No communication link with crew member/supervisors.
8. Constructing lines without safe anchor point.
9. Building fireline downhill with fire below.
10. Attempting frontal assault on fire.
11. Unburned fuel between you and the fire.
12. Cannot see main fire—not in contact with anyone who can.
13. On a hillside where rolling material can ignite fuel below.
14. Weather is getting hotter and drier.
15. Wind increases and/or changes direction.
16. Getting frequent spot fires across line.
17. Terrain and fuels make escape to safety zones difficult.
18. Taking a nap near the fireline.

Table 2. Standard fire orders.

F — Fight fire aggressively but provide for safety first.
I — Initiate all action based on current and expected fire behavior.
R — Recognize current weather conditions and obtain forecasts.
E — Ensure instructions are given and understood.
O — Obtain current information on fire status.
R — Remain in communication with crew members, your supervisor, and adjoining forces.
D — Determine safety zones and escape routes.
E — Establish lookouts in potentially hazardous situations.
R — Retain control at all times.
S — Stay alert, keep calm, think clearly, act decisively.

It is my opinion that the fire shelter is the most valuable and beneficial safety item provided to the fire fighter. Based on brief reports for the 1988 fire season, 53 entrapments have occurred and an estimated 200 precautionary deployments have taken place. The high number of entrapments are signaling a continued warning. Over 140 fire fighters found it necessary to deploy their shelters in "last report" situations in 1987. Unfortunately, one fire fighter lost his life and several others suffered serious burns. Several hundred additional fire fighters have been entrapped during the past several years. Investigation reports of these incidents revealed obvious and continued violations of the "watch out" situations and standard fire orders (Tables 1 and 2). The 1988 entrapment mentioned earlier was just a few months ago, and I remember the situation, shift plan, crews and team just as if it happened yesterday. It was an experience I'll never forget. I later talked with one of the overhead crew members who had to deploy his fire shelter. He recalled seeing the *Butte fire shelter deployment* video. Following the directions and remaining calm paid off for him. The shelter works. I want to mention that three video tapes, *Butte fire shelter deployment*, *Crank fire burnover*, and *Your fire shelter* are being shown during this conference and I encourage each of you to take the time to view them.

TRANSPORTATION

Transporting fire fighters to and from the incident still creates some problems. As stated earlier, there was an accident in 1986 involving a crew and a National Guard 4.5-tonne truck. There were four fatalities and 17 people injured. Since that accident, several changes occurred. The National Guard and using agencies reviewed their agreement extensively. Driver hours were reduced and enforced. Maintenance records were monitored and vehicles inspected regularly. Drivers were selected on experience and trained if necessary. Different sizes of vehicles were provided, and speed limits were established and followed. Based on 16 days of personal observation, the system has improved and can be used safely to move our fire fighters to and from firelines when properly supervised and managed. Another change that followed this accident was the increased usage of "spike" camps and "coyote" camps. These camps usually decrease the need to transport the fire fighter as frequently. Other safety and heath hazards increase when these camps are not supplied, cleaned, and managed properly.

WILDLAND-URBAN INTERFACE PROBLEMS

The house-trailer accident mentioned earlier and others tell us that the risks and hazards of wildland fire fighting are changing, mainly as a result of increased involvement in the wildland-urban interface. Assuring fire fighter safety in today's environment is particularly challenging because of the complexities of the interface, which subjects wildland and urban fire-fighters to hazardous conditions not normally found in their primary areas of responsibility. For instance, wildland fire-fighters are being exposed to structural hazardous materials and railroad, vehicle, and landfill fires. Urban fire-fighters must contend with wildland fires within urban developments. The situation is further complicated by the need for the protection organizations to coordinate and direct multi-agency personnel, to coordinate interagency communications and the use of specialized wildland and urban fire suppression equipment, and to manage independent homeowner actions and public safety. In order to assure adequate fire-fighter safety in the interface we must define the limits of involvement, provide for cross-training and appropriate personal protective equipment, develop preplanned agreements, share safety and health information between agencies, and educate the public.

PHYSICAL AND MENTAL CONDITIONING

The physical condition of the fire fighter is of vital importance. He or she must be both physically and mentally prepared to do the assigned job. We have established physical requirements for each job and use the "step test" to measure the physical ability of each fire fighter. Some fire fighters select to use the alternate 2.4-km run. Both methods are acceptable. I will not attempt to tell you how physically demanding fire fighting is, but I encourage you to recall the last time you were operating a shovel or pulaski, the weight of your day pack, and how exhausted you were at the end of the shift. Now add the years passed and possibly some extra weight. Each one of us in fire fighting needs to make regular physical exercise a daily part of our lives. This activity will help us to follow the first standard fire order: Fight fire aggressively, but provide for safety first.

No measurement of the mental condition has been placed on the fire fighter. But, I feel that mental condition is just as important, if not more important, than the physical demands placed on our fire fighters. A fire fighter must have the ability and a clear mind to perform and think clearly in a critical situation.

I would like to take a few minutes to discuss the importance of critical incident stress management. We are aware that many of our employees are frequently exposed to injuries, life-threatening events, or fatalities. Even the nature of our emergency work is physically and emotionally stressful. Stress comes in many forms, and every incident is different. Take for example the fourth accident I described. The crew was a regular crew who handled the entrapment very well, both physically and emotionally. Yes, there was some emotional relief when they returned to the incident command post. But, a beginning fire fighter on another crew in camp who had only listened to the radio communications during the night experienced a high level of emotional stress the next morning, much more than the entrapped crew.

It is important to recognize and realize that each of us will react differently when forced to deal with traumatic situations. I wish I could tell you that you will never experience any traumatic situations, but when you encounter them, you will be able to handle them and recognize when someone needs assistance. I might mention that all of the fire fighters (48 in total) and the overhead team attended a critical incident stress debriefing within 48 hours following the incident.

RECOMMENDATIONS

It would be wonderful if I could leave you with solutions to all of these concerns; however, the answers are very complex. Some are multi-agency and vary from location to location. You might want to consider these beginning steps to improve your immediate situation:

- Review your operation or organization, recognizing that no one knows it better than you.
- Identify the areas functioning properly and the areas that can be improved.
- If changes have occurred, adapt to them.
- If changes need to occur, get involved and make them occur.
- Organize a team; this team needs representation and input from those organizations affected. The team needs top management's support and commitment. It needs to be limited in members to a working group. A plan needs to be developed that will guide the team's efforts toward improvements.

There is one element that is the foundation for making improvements. That element is a positive attitude towards safety by all individuals and organizations involved. That attitude must begin at the top and move down throughout the organization.

During 1987, the regional management team in the Intermountain Region (R-4) of the U.S. Forest Service chartered a Delta safety team to find an approach to safety that would be positive and would place the well-being of the employees foremost. An outcome of their study was that the perceptions on the part of many people working on fires is that we talked safety, but when it came to doing the job, we emphasized production and "to hell with safety." In other words, the attitude we should be projecting in accordance with the most important fire order, "fight fire aggressively, but provide for safety first," does not always hold true in the eyes of some of our personnel. What comments would your employees tell you about safety, specifically wildland fire-fighter safety, if asked?

CONCLUSIONS

In conclusion I commend the Interior West Fire Council for including wildland fire-fighting safety as a topic on the agenda of their first annual meeting and workshop. I think all of us assign a high priority to the personal safety of our employees, including our fire fighters. Developing and maintaining a positive safe attitude begins with you and top management. It must trickle down to the ground levels where most accidents occur. We must instill in our fire fighters the attitude that there is no task worth doing at the expense of an accident or personal injury. The first standard fire order of "fight fire aggressively, but provide for safety first" will save lives when effectively practiced on our fire suppression activities, not simply stated or read.

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FIRE PROTECTION IN KANSAS: AN OVERVIEW

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ABSTRACT

This paper presents a brief description of the topography, population, vegetation, resources, and weather and how these factors determine the fire protection needs in Kansas. Five-year average fire statistics are compared with the first 6 months of 1988. The extremely high total area of 88 690 ha burned in this drought year is over 400% more than an average year. Over 700 fire departments are assisted by Kansas State and Extension Forestry and other agencies offering training, equipment, and financial help.

INTRODUCTION

Where is Kansas? What does it look like? What burns and who is there to care? I hope to answer some of these questions and at the same time straighten out some common misconceptions about the sunflower state and our plains states in general. If you walk straight south for 14 days, turn left and walk for about 12 more days you would be very close to Kansas (i.e., 1600 km south and 1400 km east). Many people think of the Great Plains only as a barren, flat, treeless wheat field with no roads and no people and of Kansas only as the home of Dorothy and Toto, Fort Riley, and Matt Dillon. Kansas instead has a wide variety of terrain, land uses, vegetation types, and population densities.

GEOGRAPHY AND DEMOGRAPHICS

The western third of the state is the High Plains country, with flat to rolling topography, most of the large wheat fields, and large farms. The population density here is the lowest in the state. Weather is typically hot and dry with less than 45 cm annual precipitation. Industry includes oil and gas in addition to agriculture.

The central third of Kansas is made up of tall grass prairie with large contiguous tracts of grassland. The topography is very hilly with hardwood timber along the numerous streams and cedar on the upland areas. An abundance of industry including aircraft and agricultural equipment is located in larger cities.

The eastern third is rolling with smaller fields and pastures and an abundance of hardwood timber. This area receives up to 100 cm of precipitation annually and is very humid. Oil and coal along with general manufacturing are the main industries. Population densities in this area are the highest in the state.

We have counties with barely 2000 people and some with 400 000. Total population is about 2.5 million, and 68% live in urban areas. Severe weather is common including ice storms, thunderstorms, and our famous tornadoes. Snow cover is usually intermittent at best. Temperatures in excess of 38°C are common in June through September and below -18°C are usually recorded each year.

THE FIRE PROBLEM

Fire Season

The fire season in Kansas follows trends in fuel moisture. Usually it is the most severe during March, April, October, and November, although we do have fires during all months. These same months present us with very erratic fire behavior and include high changeable winds (over 80 km/h), low relative humidities (5-10%), cured fuels, and very high temperatures. This combination results in rapid spread rates and dangerous fire fighting. This spring one fire burned over 20 250 ha in less than 6 hours.

Most of our large fires occur in the central third of the state because of the large grasslands, large fire districts, low population, longer fire season, and more variable weather. Also, fire is used as a pasture management tool in this area to increase desirable grass species over the invading cedars and weeds.

Fire Statistics

Average annual fire statistics include about 4300 fires burning 19 830 ha for a loss of $10.75 million. Nearly all fires are man-caused, and most are small, about 1/2 ha, but a few reach 400 ha each year.

Statistics for the first 6 months of 1988 indicate how severe drought affects our fire season. Some counties had received only 30% of normal precipitation and were 5-10 degrees warmer than normal. During that time, 4286 fires burned over 88 690 ha, with 1460 fires burning 68 230 ha in March alone. Average fire size was nearly 5 times the 5-year average. Twenty-nine fires each burned over 400 ha. Scattered thunderstorms since then have done little to help fire fighters.

FIRE PROTECTION

Suppression Forces

Fire protection in rural Kansas is provided nearly exclusively by volunteer fire departments. We have about 700 departments each with 20-30 members. Because of the volunteer nature most have a rapid turnover of personnel. Districts range in size from about 40 km² to whole counties. We have about 35 fully paid departments, mainly in larger cities, and a wide variety of combination departments. There are no state or federal suppression units in Kansas as 98% of the land is in private ownership.

Fire Equipment

Fire equipment varies widely, but the most common is a 4 × 4 with a slip-on unit or quick attack unit followed by a tanker/pumper with about 1000 L total water capacity. Nearly all fire fighting is done with water, and mutual aid agreements with neighboring departments supplement manpower and equipment. We do have a few unusual pieces of equipment such as snowjobs and choppers, and there is some retardant use.

Kansas State University's Department of Forestry Programs

Our Kansas State University's (KSU) Department of Forestry assists the fire departments in several ways. Our training thrust is directed at the wildfire aspect. We offer a two-night Basic Rural Firemanship course at the local department. This class, offered in the spring, stresses fire behavior and safety and is followed by one night in the wildfire simulator held in the fall. We also cooperate with federal and state agencies in presenting prescribed burning workshops and with state, county, and regional fire schools. We train about 1000 fire fighters annually.

At one time our fire departments used about 1800 excess military vehicles, and 800 are still in use. Most rural fire departments began operation using these trucks and some still haven't updated. We also operate the Rural Community Fire Protection program and have cost-shared $1.6 million of these federal dollars. Priorities include protective clothing, breathing apparatus, and slip-on units.

We provide fire prevention materials directly to our elementary school teachers utilizing Smokey Bear. Our four Smokey suits are scheduled on a regular basis, and we do work with boy scouts, 4-H clubs, and schools to present the fire prevention message. We cooperate with the U.S. National Weather Service to issue rangeland fire danger warnings and are working with Nebraska to calibrate the satellite remote sensing of percent green (Westover and Sadowski 1987). We have also helped most fire districts organize and become operational and are working toward county-wide districts. Most of our rural-urban interface occurs in our grasslands with farmsteads and other residences, but we do have other interface areas as well.

Other Agency Assistance

Other agencies that assist our fire departments, especially in training, are the Kansas Firefighters Association, Fire Chiefs, Fire Service Instructors and KSU. They train in the non-wildfire type fires. Industry and insurance companies offer specialized training in elevator fires and chemical incidents among others.

CONCLUSION

Kansas may be known as the Land of Oz and as a wide place between the Ozarks of Missouri and the Rockies of Colorado, but we are also a place of great variety, excellent college basketball, and not-so-excellent football and a place of warm weather and warm people.

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RAY ASLIN is an Extension Forester (Fire Control) with the State and Extension Forestry Service of Kansas State University (KSU) located at Manhattan. He received B.Sc. (1972) and M.Sc. (1975) degrees in forestry from the University of Missouri. Ray has worked for KSU State and extension forestry since 1975, having served in the southwestern and northwestern regions of the state as the Area Forester prior to assuming his present position in March 1987.

INTERAGENCY WILDFIRE COOPERATION IN THE BLACK HILLS REGION

Kenneth Terrill
Division of Forestry
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Pierre, South Dakota

ABSTRACT

This paper offers an overview of the Black Hills Fire Council, which comprises numerous wildland, urban, and rural fire and resource management organizations in the western quarter of South Dakota, northeastern Wyoming, and southeastern Montana. This interagency group has worked together on various cooperative projects (e.g., overhead teams, training, prescribed burning, fire prevention) for several years now. The attitude taken by the council's member agencies has greatly contributed to a cost-effective approach to wildfire management in this region of the United States.

INTRODUCTION

This paper reviews the progress that is being made between three national parks, two national forests, three state forestry agencies (South Dakota, Wyoming, and Montana), two counties (in Wyoming), and 43 local fire departments to more effectively manage fire problems in the Black Hills.

The elevation of the Black Hills is approximately 1067 m, and the area they cover is approximately 556 692 ha. The predominant vegetation type is ponderosa pine, with a grass understory. A unique quality of this vegetation is that ponderosa pine regeneration is very prolific in areas where the soil has been disturbed either by fire, construction, or other causes. Because of this prolific growth and the exclusion of fire for many years, this area is very prone, in dry years, to relatively large, high-intensity wildfires. This area of the country averages about 200 fires per year. The annual area burned amounts to about 1012 ha.

BLACK HILLS FIRE SUPPRESSION AGREEMENTS

In the 1950s, several agencies began an effort to combat these fires on an interagency basis. In the early 1960s, agreements were put into place between the various federal, state, and county agencies that stated the responsibilities of the various entities as they are related to forest fire suppression, prevention, training, etc. One of the main agreements is with the U.S. Forest Service (USFS) (Black Hills National Forest) and the South Dakota Division of Forestry, and it divides the area into various fire protection management units that dictate how the fire suppression effort will be conducted in each unit. The units in South Dakota are known as the state fire protection unit, offset, and reimbursable fire protection units because, by state law, the South Dakota State Forester is responsible for the forest fire suppression on state and private lands.

The U.S. National Park Service is responsible for their own fire suppression efforts and must have agreements with the South Dakota Division of Forestry and the USDA Forest Service to cover their fire protection needs. All wildfires occurring on lands within the Black Hills administered by the USDI Bureau of Land Management are suppressed by the South Dakota Division of Forestry by prior agreement.

Each of the counties in Wyoming that border the Black Hills has an agreement with the Black Hills National Forest that provides for the management of any fires when they occur by USDA Forest Service personnel. The USDA Forest Service also has an agreement with the Wyoming State Forester that covers how wildfires are to be suppressed on the state lands in and around the Black Hills.

FORMATION AND PURPOSE OF THE BLACK HILLS FIRE COUNCIL

In the early 1970s, a group of various fire management agency personnel met to form what is known today as the Black Hills Fire Council. The main intent of the initial meetings was to get to know each other, to work towards helping each other in the delivery of various wildfire suppression training courses, and to develop ways that agencies could cooperatively share suppression personnel on wildfires.

Overhead Teams

After the first few years of annual meetings, the council decided to form an interim interagency fire suppression overhead team that could be used, as the situation warranted, on any wildfire occurring in the Black Hills region regardless of the jurisdiction and before one of the formal Class I or II teams arrived on the scene. To establish this interim overhead team, one of the first things that was decided was the number and types of positions that were needed to allow this team to work effectively. Each position has a fully qualified, partly qualified (i.e., has the "paper training", but not all of the required experience), and trainee category. This helps manage the various interagency personnel and determines in what positions they can be used. Each winter, council members meet and select the specific personnel that will participate as members of the interagency overhead team for the upcoming fire season. Emphasis is put on ensuring that the interagency concept is maintained in order to produce a balance in the make-up of the team's participants. All positions, from the incident commander position down to the crew boss position, are reviewed and approved by the council members annually.

Training Needs

Another task that the council works on every winter at its annual meeting is developing the training needs of the various member agencies and determining what fire positions in the overhead team will need to be filled in the future and gear the training efforts accordingly. After the various training needs are identified and the priority for the courses to be presented are determined, each agency offers to take the lead role in the presentation of one or two of the courses for the upcoming year. The lead role involves lining up the classroom materials, sending out announcements, and being responsible for finding qualified instructors to teach the course. Instruction is shared by the various agencies involved so no one agency is forced to present all of the course. The sharing of qualified instructors also insures that each course has a true interagency flavor when being presented to the students.

In 1985 the council agreed to adopt the Incident Command System (ICS) for the management of its fire suppression efforts. This has greatly enhanced the efforts of the fire council in organizing and planning the fire training efforts.

In January of each year the council now publishes its proposed training calendar for the upcoming year and a half. This is provided to the various agency members so they can develop their own in-house training plans.

Fire Prevention

Fire prevention efforts are also now presented on an interagency basis at the local level, whether it be assisting each other in a fire prevention presentation at a local school during fire prevention week or entering an agency vehicle in a local parade complete with Smokey the Bear. These efforts are being done more and more on an interagency basis. The latest effort is in working with local homeowners associations and teaching them how to make their home more fire safe from the threat of wildfires. In working with the local volunteer fire departments, the state, county, and federal agencies are better able to reach forest homeowners and tell them how they can more effectively make their homes more resistant to destruction by wildfire. Presentations are made jointly to the public, and the long-term message being conveyed by the agencies is that by working together, they are more effectively using the public's tax dollars.

Prescribed Burning

One more area where the council is working together is in the area of prescribed burning. Joint prescribed fires are now conducted, which involve a mix of land ownerships when the actual unit to be burned is conducted. This allows for the prescribed fire planning and execution to take advantage of natural barriers, such as roads and streams, and saves having to build new fire lines along the various property lines that may occur within a burning unit. For these prescribed fires involving mixed land ownership, only one burning plan is prepared, and it covers the whole area. This saves having each agency develop its own individual prescribed fire plan.

On those days when the prescribed fires are to take place, whether they are on land of mixed ownership or not, they are done by an interagency team that works together in conducting the overall operation. It is not uncommon to see all agencies contribute personnel to a prescribed fire, all the way from the local volunteer fire department personnel to state and federal agency staff. Quite often these prescribed fires are used as a training exercise to sharpen the skills of the individuals involved, so when they are needed for wildfire suppression they can work more effectively together as a team. In order to ensure that agency personnel are trained to the same level, the council has developed interagency standards that are used as a guide to fill the various positions on the overhead team, whether it be for a prescribed fire or a wildfire.

THE 1988 EXPERIENCE

During the 1988 fire season the council's efforts really paid off. The Black Hills experienced 368 wildfires, which burned over 9755 ha. The occurrence of two large project fires required bringing in Class I overhead teams to help in the management of these wildfires. The Galena Fire started on July 5 and continued actively burning until July 10, eventually consuming 6794 ha. This fire burned mostly in Custer State Park (an area 29 542 ha in size), threatened many park structures, and at one time threatened the community of Keystone and Mt. Rushmore National Monument.

The second fire, known as the Westberry Trails Fire, started on July 26 and was not declared controlled until July 31. It finally covered 1554 ha and burned up to the west side of Rapid City, South Dakota (population: approximately 50 000). This fire burned through, as well as near, eight subdivisions, consuming 15 permanent residences and threatening 200 other homes. Because of the past efforts of the Black Hills Fire Council and also the adoption of the ICS approach to fire suppression, the control aspects of this fire went very well. The public was also well served in the effective management of this incident.

FUTURE DEVELOPMENTS

Looking toward the future, the council, along with the Keep South Dakota Green Association, is sponsoring a symposium entitled "Protecting People and Homes from Wildfire in the Black Hills," to be held in Rapid City on April 10-11, 1989. This conference will try to address, at the local level, how we will work to deal with the major urban-rural interface fire problem we have in the Black Hills. The target audience for this conference will be city and county planners, local and state elected officials, subdivision developers, and the local homeowners in the various subdivisions scattered throughout the Black Hills.

As time passes, I am sure there will be other challenges that the Black Hills Fire Council will have to deal with; but because it is done on an interagency basis, I'm confident that the public will be served in the most effective way possible.

THE AUTHOR

KEN TERRILL is a Fire Management Specialist with South Dakota Department of Agriculture's Division of Forestry in Pierre, South Dakota. He received an A.Sc. degree in 1970 from the Bottineau Branch of North Dakota State University in Bottineau, North Dakota. In 1972, he received his B.Sc. degree in forestry from Utah State University in Logan, Utah. Ken started in forestry work with the South Dakota Division of Forestry in Rapid City (1974-77) as an Assistant District Forester and then as the Fire Training Specialist for the Division of Forestry (1977-79). He assumed his present position in 1979 where he is in charge of the South Dakota Division of Forestry's fire management program as their Fire Management Specialist, where he works directly with the State Forester and helps him manage the division's fire program on a statewide basis.

COMMERCIAL DISPLAYS AND POSTER SESSION

Opening Remarks: *General Chairman*

John E. Benson

Forest Protection Branch
Alberta Forest Service
Edmonton, Alberta

I made a comment this morning about the importance of equipment development within the wildland fire community. I may be biased but I really believe that our vendors are truly interested in how their product works on fires. They will spend the additional time to research and develop the product to suit our needs. Most of them spend a good deal of time with our field staff to make the product operationally sound. I sincerely welcome each and every one of the vendors to this meeting and workshop. We have a special three and a half hour period set aside this evening for you to meet, discuss, and socialize with the vendors and exhibitors in attendance.

Owen J. Bolster
Forest Protection Branch
Alberta Forest Service
Edmonton, Alberta

I'd like to expand on John Benson's opening remarks for a moment. It's certainly becoming evident, at least in western Canada, that many of the companies have a commitment that goes beyond simply making a profit. They have a genuine concern about what happens to our wildlands! As John has stated, they do not hesitate to come out to the field or go to meetings such as this one, at their own expense I might add, in order to see how their product is performing, how it can be improved or modified to do a better job for us. I think the turnout at this meeting is a good example of this—in short, it's a win-win situation. We wanted to recognize this relationship by setting aside one evening during the meeting where we could meet in a relaxed atmosphere to share our thoughts, discuss new products or simply swap "fire stores." We hope this evening will assist us in this objective.

THE AUTHOR

OWEN BOLSTER is the Fire Operations, Training, and Equipment Coordinator with the Alberta Forest Service's (AFS) Forest Protection Branch (FPB) and works at the Provincial Forest Fire Centre in Edmonton, Alberta. He graduated from the Forest Technology School at Hinton, Alberta. Owen joined the AFS in 1956 and has served in a variety of field and headquarter positions: Timber Cruiser (1956-58), Photogrammetrist (1958-62), Assistant Ranger (1962-64), District Ranger (1964-73), Chief Ranger (1973-78), FPB Fire Control Dispatcher (1978-79), FPB Head—Air Administration Section (1979-85), and FPB Fire Prevention Coordinator (1985-87) prior to assuming his present position.

LIST OF VENDORS AND EXHIBITORS

Compiled by

Owen J. Bolster
Vendor/Exhibitor Coordinator

Alberta Government Telephones, Mobile Communications
Canadair Inc.
Canadian Helicopters Limited
Chemonics Industries (Canada) Ltd.
Compuheat Services Canada Ltd.
Conair Aviation Limited
Fireflex Manufacturing Limited
Fleck Bros.
Forest Technology Systems Ltd.
Global Forest Fire Services Ltd.
The Mallory Company
Marius Systems
Monsanto Company
Northern Eagle Diagnostics
Premo Plastics Engineering Ltd.
Simplex Manufacturing Company
Sims Fiberglass Co.
Travel Alberta
Tydac Technologies Inc.
Wajax-Pacific Fire Equipment
Wilderness Fire and Resource Group Inc.
Williams Electronics Ltd.

EXTENDED ABSTRACTS OF POSTER PAPERS

Martin E. Alexander
Poster Session Coordinator

PERSONAL COMPUTER-BASED FIRE MANAGEMENT INFORMATION SYSTEMS

Ian R. Methven, Ugo Feunekes, and A.G. "Kim" Mann
Resource/Environment Management Systems (R/EMS) Research Ltd.
Fredericton, New Brunswick

Fire management is immediate. It is unique among forest management activities because it is vulnerable to day-to-day and hour-to-hour changes in fire weather, fire danger, and fire behavior, and because it must respond to these changes in the same time-frame. In spite of this telescoped time-frame, the fire manager needs as much if not more information than any other forest manager, and this information must be presented in a way that supports rapid decisions. The problem then boils down to rapid processing of large amounts of data and its transformation into information that can be rapidly assimilated. These unique requirements of fire management lead to the need for a dedicated, high-speed processing capability and high quality graphics for the display of information. The most cost-effective and flexible way to meet these needs is through the use of personal computers.

This poster displays examples of personal computer-based fire information programs including 1) spatial display of fire danger from the Canadian Forest Fire Weather Index (FWI) System codes and indexes; 2) spatial display of fire spread rates derived from the application of the Initial Spread Index of the FWI System to fuel types and slopes based on the Canadian Forest Fire Behavior Prediction (FBP) System; 3) fire growth over heterogeneous fuels; and 4) the effect of different fire regimes on age class distribution, growing stock, and wood supply from a forest.

All these programs and models run rapidly on personal computers with graphic cards to provide the manager with timely and instantaneously accessible information on fire danger, predicted fire behavior, and fire effects.

A CARTOGRAPHIC HISTORY OF FOREST FIRES IN ALBERTA

Gilles P. Delisle[1], **Martin E. Alexander, and Murray E. Maffey**
Northern Forestry Centre
Forestry Canada
Edmonton, Alberta

Forest fires ≥ 200 ha in gross area that occurred in the province of Alberta between 1931 and 1983 were compiled and mapped. This 53-year record of Class E fires is based on available individual forest fire report forms obtained from the Alberta Forest Service and Canadian Parks Service. Six 1:500 000 scale color-coded map sheets were produced of four provincial quarters (Fig. 1); two quarters were represented twice because of the large number of overlapping fire boundaries (Table 1). A companion report provides a chronological listing of the 1678 plotted fires, sorted by year, name and/or number, location, size, and cause, linked to map reference number. Class E fires have accounted for, on average, 85% of the total area burned per year in Alberta during the past 30 fire seasons. Copies of the report and maps prepared by Delisle and Hall (1987) are available (no charge) upon request from:

Northern Forestry Centre
Forestry Canada
Northwest Region
5320 - 122 Street
Edmonton, Alberta, Canada
T6H 3S5

Attention: Fire Management Research

REFERENCE

Delisle, G.P.; Hall, R.J. 1987. Forest fire history maps of Alberta, 1931 to 1983. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Rep. + maps.

Table 1. A list of the *Forest fire history maps of Alberta, 1931-1983*

Map quarter	Area number	Sheet number	Time frame	Time period 1	Time period 2	Time period 3
NW	1	1 of 2	1931-1948	1931-1940	1941-1943	1944-1948
NW	1	2 of 2	1949-1983	1949-1966	1967-1980	1981-1983
NE	2	1 of 1	1931-1983	1931-1948	1949-1980	1981-1983
SW	3	1 of 2	1931-1948	1931-1940	1941-1943	1944-1948
SW	3	2 of 2	1949-1983	1949-1966	1967-1980	1981-1983
SE	4	1 of 1	1931-1983	1931-1948	1949-1980	1981-1983

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[1] Present address: 335 Rabastalière Est., St-Bruno, Québec J3V 2A7.

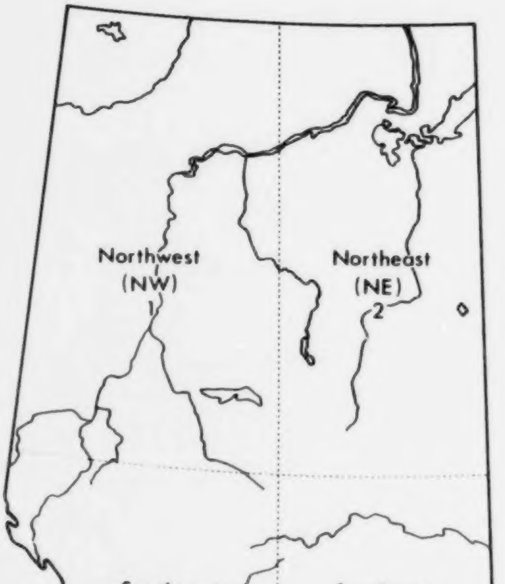
Northwest
(NW)
1
Northeast
(NE)
2
Southwest
(SW)
3
Southeast
(SE)
4

Figure 1. Geographical index to the *Forest fire history maps of Alberta, 1931 to 1983.*

MOUNTING THE ATTACK ON WILDFIRE: THE VIDEO

Avery C. Ascher and Martin E. Alexander
Northern Forestry Centre
Forestry Canada
Edmonton, Alberta

This videotape production (1987, 18 min) offers an overview of the co-operative experimental burning project being conducted at Big Fish Lake in north-central Alberta since 1984 by Forestry Canada and the Alberta Forest Service (AFS) (Ascher 1987). The project study area is located within the Footner Lake Forest, 100 km northeast of the local AFS headquarters in High Level, Alberta. The research objectives are directed at strengthening the empirical data base associated with the quantitative prediction of fire behavior in the black spruce-Labrador tea-cladonia fuel type of western and northern Canada. The footage focuses on the documentation undertaken by Forestry Canada fire research team prior to, during, and following each experimental fire on plots ranging in size from 0.1 to 1.0 ha. This includes pre- and post-burn fuel assessments (i.e., forest floor, downed-dead roundwood, shrubs, and tree crowns), vegetation inventory, fuel moisture sampling, fire weather observations, rate of spread monitoring, and depth-of-burn measurements. This video documentary offers a general introduction to a specific regional example of Forestry Canada fire behavior research associated with the development of the Canadian Forest Fire Danger Rating System and is suitable for viewing by a wide variety of audiences. As pointed out in the presentation, the Big Fish Lake Experimental Burning Project "...shows the gains that can be made when fire researchers and fire managers collaborate in producing, or refining, a valuable fire management tool." To obtain a copy of the videotape *Mounting the attack on wildfire*, please send a formal written request and a blank VHS (1/2-inch) tape to:

Northern Forestry Centre
Forestry Canada
Northwest Region
5320 - 122 Street
Edmonton, Alberta, Canada
T6H 3S5

Attention: Fire Management Research

A copy of the script is available from the authors upon request.

REFERENCE

Ascher, A. 1987. Mounting the attack on wildfire. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Timberlines 2:2-3.

DETERMINATION OF FUEL TYPES COMMON TO THE GRANDE PRAIRIE FOREST USING THE TYDAC/SPANS GIS SOFTWARE

Robyn G. Usher
Integrated Environments Ltd.
Calgary, Alberta

This study was undertaken for the Alberta Forest Service's, Forest Protection Branch to determine fuel types common to the Grande Prairie Forest in west-central Alberta using the TYDAC/SPANS GIS software. The study was part of a larger program to determine daily presuppression resource requirements and to assist in initial attack development planning. Fuel types were determined using the Alberta Forest Service's AFORISM database and the fuel type classification scheme embodied in the Canadian Forest Fire Behavior Prediction (FBP) System as developed by Forestry Canada (Lawson et al. 1985). This database was compiled using Phase III forest cover maps and provides detailed forest stand data. A quarter section summary file of this information has also been compiled. Fuel types were calculated using the quarter section summary file and the development of a fuel code program using dBase III Plus. A program was developed to determine the fields of information needed to establish quarter section fuel types. After several iterations four fields were selected; forest class, density, date of stand origin, and species percent occurrence. Calculated fuel types were subsequently imported into SPANS as quarter section point files. Because of the large size of the database (59 700 records), it was subdivided into data subsets. The SPANS Voronoi feature was used to display the locations of quarter sections for which AFORISM data were available. Attribute files containing quarter section fuel types were created and used in conjunction with the Voronoi maps to display fuel types by quarter section. Area analyses were undertaken to determine the percent occurrence and area of each fuel type. Maps and area analyses were prepared for the 14 Initial Attack Areas (IAs) that make up the Grande Prairie Forest. These maps will be used in conjunction with other data to help allocate fire-fighting resources.

REFERENCE

Lawson, B.D.; Stocks, B.J.; Alexander, M.E.; Van Wagner, C.E. 1985. A system for predicting fire behavior in Canadian forests. Pages 6-16 *in*: L.R. Donoghue and R.E. Martin, editors. Proceedings of the Eighth Conference on Fire and Forest Meteorology. Soc. Am. For., Bethesda, Maryland. SAF Publ. 85-04.

WILDFIRES IN THE KANANASKIS WATERSHED

Edward A. Johnson, Gina I. Fryer, and Dana R. Wowchuk
Division of Ecology, Department of Biological Sciences and
Kananaskis Centre for Environmental Research
University of Calgary
Calgary, Alberta

The present age-distribution of the forest in the 130 000-ha Kananaskis watershed has not been in equilibrium with any fire frequency for at least the past 400 years. The lower subalpine forests of lodgepole pine and Engelmann spruce require fires within the life span of the post-fire generation of trees to effectively reproduce. The high intensity wildfires kill the canopy trees and remove a large quantity of the duff, providing the preferred seedbed for pine and spruce.

Fire Frequency and Climate Change

The fire frequency in the Kananaskis watershed has varied both spatially and temporally over the past 400 years. Spatially, the watershed was found to be divided into two climatically different units corresponding to the main and front range of the Rockies. Temporally, both climatic units exhibited a change in fire frequency in about the year 1730. The fire cycle for the period prior to 1730 was 60 years in the main range and 30 years in the front range. The fire cycle increased in the period 1730-1980 to 130 years in the main range and 95 years in the front range. The shift in fire cycle length in 1730 appeared to be related to the change in climate associated with the Little Ice Age. A dendroclimatic study using Engelmann spruce reconstructed a warm-dry climate (from 1520 to about 1660) and a cooler-moister climate (from about 1661 to 1980).

Factors Affecting Fire Behavior

Large fires, such as the 1936 Galatea Creek Fire, are important in shaping the fire frequency in the Kananaskis Valley. These fires appear to follow a characteristic synoptic weather pattern and have relatively predictable effects on the vegetation. The Galatea Creek Fire in August 1936, followed a period of fuel drying caused by a blocking high pressure system. Wind, not fuel type or elevation, played the major role in fire behavior and resulting burn pattern. Fire effects were reduced in areas adjacent to water bodies and in valleys upwind of the fire's spread direction. Almost complete canopy mortality was caused by frontal fire intensities 9000 KW/m. Although the fire size was greater than the mean dispersal distance of Engelmann spruce seeds, the composition of the forest was not significantly changed. The low moisture content of the duff ensured adequate fuel consumption for conifer seedbed preparation.

European Activity and Vegetation Change

The age and composition of the vegetation in the Kananaskis has not changed appreciably since logging, mining, and hydroelectric development began in 1883. A comparison of an 1883 forest survey to another done in 1972 revealed that sites populated by lodgepole pine or Englemann spruce tended to remain the same between surveys. The fire reconstructions for 1730 to 1972 showed no change in fire frequency associated with European activity. It appears that natural processes of site differences and fire occurrence are still the dominant factors affecting changes in vegetation composition and age structure. These conclusions were drawn from systematic analysis of historical records that covered the entire watershed and were not based only on old photographs and contemporary accounts.

The following is a list of some of our published research on the fire history in the Kananaskis watershed.

Fryer, G.I.; Johnson, E.A. 1988. Reconstructing fire behaviour and effects in a subalpine forest. J. Appl. Ecol. 25:1063-1072.

Johnson, E.A.; Fryer, G.I. 1987. Historical vegetation change in the Kananaskis Valley, Canadian Rockies. Can. J. Bot. 65:853-858.

Johnson, E.A.; Fryer, G.I. 1989. Population dynamics in lodgepole pine-Engelmann spruce forests. Ecology 70:1335-1345.

Pruden, M.A.; Fryer, G.I.; Johnson, E.A. 1986. Fire frequency and old trees in the southern Canadian Rockies. Pages 175-179 *in* G.C. Jacoby and J.W. Hornbeck, eds. Proceedings of International symposium on ecological aspects of tree-ring analysis. U.S. Dep. Comm., Natl. Tech. Inf. Serv., Washington, D.C. Conf-8608144.

PRESCRIBED FIRE IN NATIONAL PARKS OF WESTERN CANADA: PAST EFFORTS AND FUTURE INITIATIVES

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Western Region
Canadian Parks Service
Calgary, Alberta

Alan L. Westhaver
Elk Island National Park
Canadian Parks Service
Fort Saskatchewan, Alberta

Fire management in Canada's national parks is rapidly evolving to include aspects of fire use in addition to the traditional emphasis on fire suppression. Since 1979, when Canadian Parks Service (CPS) policy formally recognized fire as a natural process, national parks in the Western Region have developed fire and vegetation management programs that incorporate prescribed fire.

Although the overall objective is to reintroduce fire as a natural component of park ecosystems, early prescribed burns were relatively small and were conducted primarily to meet research and training objectives. As park wardens develop expertise, prescribed fires are increasing in size and complexity. The use of fire is currently approaching an operational phase in order to meet ecological objectives. Fire suppression capabilities have grown correspondingly.

Elk Island National Park is currently conducting prescribed fires for the purpose of restoring aspen parkland vegetation that existed prior to the park's establishment and the subsequent fire suppression era. Banff National Park has conducted numerous prescribed fires in the montane and lower subalpine forests culminating with the 2300-ha Minnewanka I unit prescribed fire in April, 1988. Jasper National Park has nearly completed background studies and successfully conducted the 65-ha Henry House I prescribed fire in 1988. As well, Yoho, Kootenay, Waterton Lakes, and Revelstoke-Glacier national parks are actively involved in data collection and analyses required to implement the use of fire for resource management purposes.

Seven of the nine national parks in the CPS Western Region have approved fire management plans that guide fire suppression and the implementation of fire use. These plans are preliminary ones, pending the results of additional fire history and fuels appraisal studies, the final compilation and analysis of fire weather data bases, and ongoing studies relating to fire effects on vegetation and wildlife.

Recent fire management initiatives include the initiation of fuel reduction (hazard abatement) programs in high visitor use areas, the development of prescribed fire techniques for use in continuous natural forest stands, increased use of geographic information systems and other computerized decision making aids, the formation of regional overhead teams, and increased cooperative activities and resource and cost sharing with national and provincial fire management agencies and educational institutions. All of these initiatives and programs have been integrated with those of other CPS regions through the recent efforts of the CPS National Fire Management Committee.

Initiatives and programs discussed above will help to increase knowledge and understanding of fire management issues in Canadian national parks, provide for better management of park resources, and allow greater progress in a time of fiscal restraint.

ACKNOWLEDGMENTS

The authors would like to thank Brian Wallace (Jasper National Park) and Tim Laboucade (Banff National Park) for their assistance in the preparation of the poster paper display.

DUFF MOISTURE AND SOIL MOISTURE REDUCE FIRE IMPACT

Roberta A. Hartford and William H. Frandsen
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U.S. Department of Agriculture, Forest Service
Missoula, Montana

Slash fires often lead the observer to assume that great amounts of heat flowed downward elevating the mineral soil to very high temperatures. In contrast, smoldering ground fires lead the observer to assume that little or no heat was delivered to the mineral soil.

The duff (fermentation and humus horizons) can act either as a barrier to the downward flow of heat when the moisture content is high or it can be ignited and bring the combustion zone directly in contact with the mineral soil when the moisture content is low.

Slash and ground fires are compared having the same duff depth (6 cm) and litter moisture content (11% on a dry weight basis). The litter was 1 cm deep, and rotted wood was common in the humus for all areas. The comparison was obtained from two prescribed fires for slash reduction and one ground fire. The duff and mineral soil in the slash fires had a higher moisture content, 25-75%, (typical of spring) than the duff and mineral soil in the ground fire, which was 10-20% (typical of late summer).

Temperature profiles obtained from the litter surface, through the duff, and into the mineral soil indicate the temperature versus time distributions at specific depths and the duration of the heat treatment.

The significant feature shown in the time temperature histories was the difference in the overall duration of heating above lethal temperature (60°C) in the duff. The duration above 100°C lasted 1.0-2.5 h and was reached only in the upper duff, even in the presence of slash. In contrast, duff smoldered in the ground fire 16 h after the upper portion of the duff reached 100°C and the combustion zone reached the mineral soil surface.

When complete removal of the duff is not a silvicultural requirement, duff and soil can be protected from lethal temperatures and long duration heating if burning occurs when the moisture content of the lower portion of the duff and the mineral soil are above 35%. In the absence of slash, the mineral soil should be adequately protected if the moisture content is above 25%.

USE OF NOAA AVHRR SATELLITE DATA FOR FOREST FIRE ASSESSMENT: A CASE STUDY

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University of Alberta
Edmonton, Alberta

On June 29, 1986, a multiple fire broke out in the area southeast of Inuvik, Northwest Territories. Several of the fires merged, resulting in the development of three major fires—EV019 and EV016 on the north side of the Mackenzie River, and EV014 on the south side. As part of an independent course of study in the Department of Forest Science at the University of Alberta, a case study was initiated to obtain spatial and temporal assessment of the Inuvik forest fires using digital satellite imagery available from the U.S. National Oceanic and Atmospheric Administration (NOAA). The NOAA satellite series program was developed to provide information to assist various meteorological, oceanographic, and hydrologic services. Since the satellites were first launched in 1970, the application of NOAA satellite imagery for purposes other than weather analysis and forecasting have been investigated. The advanced very high resolution radiometer (AVHRR) sensor onboard the NOAA satellites operates on four bands; one visible, one near-infrared and two thermal infrared bands. Channel 3 (3.55-3.93 m) is very sensitive to high temperature sources such as forest fires. Under ideal conditions, NOAA AVHRR Channel 3 can provide day and night subresolution detection of forest fires. Channel 3 pixels saturate at 321°C with no "spill-over" effect into adjacent pixels (Matson and Dozier 1981). Flaming combustion temperatures (800-1000°C) exceed this level.

The ARIES II digital analysis system at the Alberta Remote Sensing Centre in Edmonton was used to analyze two NOAA tapes. Although four times daily coverage is provided by the NOAA satellite series, only two tapes with relatively cloud-free imagery were available for this study. The study area was near nadir. The NOAA satellite series provides a full spatial resolution of 1.1 km at nadir. Fire size (i.e., actual active fire perimeter) and area burned were estimated using a density slice method. Flannigan (1985) used a multispectral approach (i.e., AVHRR channels 3 and 4 temperature differentiation) developed by Dozier (1981) to identify fire pixels in their study area. Although this approach is preferred to identify subresolution high temperature sources, the density slice method provided a relatively fast and easy procedure to classify fires EV014 and EV016. Clouds obscured fire EV019. Three slices or themes were selected. Channel 3 pixels with digital numbers (DNs) ranging from 0 to 1 were considered saturated. The pixels with DNs ranging from 2 to 9, although not saturated, represented "hot source" areas. The third theme (DN range of 10 to 115) highlighted the recently burned area (excluding water bodies) and adjacent older burns (i.e., prior to 1986). On July 13, 1986, fire EV016 was estimated by pixel count to be approximately 408 km^2. Classifications were made for fire EV014 and EV016 (Table 1). Because adequate time-series image data (i.e., tapes) were not available, estimates of fire growth could only be made from NOAA Channel 3 prints.

The application of NOAA AVHRR satellite data to provide supplementary fire detection has proved useful in the Northwest Territories. The Atmospheric Environment Service (AES) in Edmonton, Alberta, provides NOAA infrared imagery to the Government of the Northwest Territories Territorial Forest Fire Centre in Fort Smith via a telecommunications line. On July 20, 1987, NOAA satellite Channel 3 images showed 13 forest fires in the Northwest Territories that had not been discovered by conventional means. If a digital analysis system is available, NOAA AVHRR satellite data may provide information other than fire detection. The limited results of this case study suggest that NOAA satellite data may be useful to provide the following information: 1) relative estimates of current fire size and shape and total area burned; 2) relative estimates of fire growth if time series image data are available; 3) indication of areas of greatest fire activity (i.e., the highest intensity); and 4) smoke transport behavior. NOAA satellite imagery may be particularly useful to assess very large fires in undeveloped areas such as the 1986 Inuvik fires.

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Table 1. Digital number (DN) classification for fires EVO14 and EVO16 at 2139 h Mountain Standard Time on July 13, 1986 (2139 h MST)

(DN) values	Approximate area (km²)	
	EVO14 fire	EVO16 fire
0-1	2	1
2-9	25	29
10-115	300	320
0-115	327	350
Total[a]	388	408

[a] Includes water bodies and unburned areas.

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APPLYING NEW TECHNOLOGIES TO FOREST FIRE MANAGEMENT

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The Intelligent Fire Management Information System (IFMIS) is a prototype microcomputer-based decision support system being developed by the Northern Forestry Centre for dispatching fire suppression resources to wildfires. It uses PROLOG, a fifth generation computer language, as the basis for its development. An integrated relational data base manager using structured query language (SQL) is an important component of the system. With SQL it is possible to use existing fire management data bases directly with minimal or no modification. Structured query language is easily learned and can be used interactively to build custom reports from the data base. The system also incorporates an expert system shell for encoding agency policies and dispatcher expertise into knowledge bases. These knowledge bases, when used in conjunction with traditional fire management data bases and mathematical programming, can be used to provide "expert-like" dispatch recommendations. These recommendations, along with graphical and mapped displays of fire weather, fire behavior, geographic data, and resource location displays can provide fire managers with useful tools for dispatching resources to wildfires.

VIDEODISC/MICROCOMPUTER TECHNOLOGY IN WILDLAND FIRE TRAINING

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The Forest Technology School (FTS) at Hinton, Alberta, is currently spearheading the development of several wildland fire training tools employing the use of interactive video in cooperation with Access Television Network, the Alberta Forest Service, and the Maniwaki Technology Transfer Centre. This is a powerful new medium bringing together the excellent graphics and visual impact of video with the interactivity, versatility, and responsiveness of the microcomputer. For students using this technology, retention of information is up 20-40%, learning time is down 20-40%, and student interest is up 35%. Videodisc training is cost-effective due to its portability, which means less time away from the job and reduced travel and expenses. Interactive video is particularly effective in simulations where realistic visual information is required, where the procedures are too dangerous, or where equipment is too rare or expensive to use for training purposes. Developments include an interactive training course on wildfire assessment, a three dimensional (3-D) fire growth model, and a replacement to the existing FTS fire control simulator.

Wildfire Assessment Course

An interactive videodisc on wildfire assessment is being developed to train students on how to properly conduct an initial fire assessment. The 6-hour course is divided into three units, the first (Unit I) of which reviews the fire triangle and then tutors the learner in the prediction of fire growth. Unit II presents both ground and air attack approaches to suppression and then takes the learner through several steps in conducting a fire assessment. Unit III, a key feature of this course, will allow the learner to apply acquired knowledge to conduct an assessment and direct resources through the use of interactive simulation in several wildfire environments.

Information for various fire-fighting resources, categories of fuel types, and definitions and descriptions of acronyms can be accessed by the use of on-screen help and function keys. Relevant video or graphic images will emphasize the information required prior only to displaying the necessary text screens. The 3-D fire growth model will be integrated into the course, enabling students to observe fire progress in a graphic form, to vary fuel, weather, and topography types, and to observe results. The capability of the computer-based format to ask questions and provide remedial assistance in this course will be used throughout each lesson to guide the student in meeting certain learning objectives. Computer-managed instruction capabilities of the software will keep track of student progress through ongoing evaluation of question and answer response and "time to completion" factors. System hardware consists of an IBM or equivalent family of microcomputer married to a laser disc player and color monitor. This equipment is quite portable, which allows training to come to the students rather than have the students go to the training and incur unnecessary expenses in terms of time and money.

Fire Growth Model

The basis for the fire growth model is the 3-D perimeter growth model originally developed by Peter H. Kourtz of Forestry Canada, Petawawa National Forestry Institute, Chalk River, Ontario. Using a microcomputer, actual contour elevation information and digital forest inventory data for a certain area is displayed on a graphic screen in a 3-D presentation. An ignition point grows according to fuel weather and topography. This model is interactive in that the learner can input any combination of fire behavior parameters in order to experiment with "what if..." scenarios expending extensive resources and destroying large areas at minimal cost. The learner may also watch fire lines being built between two points progressing at a rate consistent with the type of resource employed (i.e., air tankers, cats, buckets, ground crews). Flame, smoke, spotting, and burned over area will also be incorporated for effect. It is intended that the growth model be used to document fire spread and effect of resources for use in both the fire simulator and for problem simulations utilized in the wildfire assessment course.

Fire Control Simulator

Laser disc technology allows realistic presentation of forest fire visuals using both high resolution color video technology and high fidelity sound. The fire control simulator that makes use of this technology will be no exception. The simulator will be employed in a theater setting whereby the learner(s) will be able to apply their knowledge of fire behavior to lifelike scenarios requiring management decisions. Video segments on a movie screen will depict actual behavior of a wildland fire, the deployment and effect of resources selected to control that fire, and visual on-screen interaction of any key role players required (i.e., dispatchers, towermen overhead, and pilots). Any video segment can be summoned within fractions of a second by either manual control from a keyboard or automatically by depressing the appropriate role player's microphone switch. It is intended that the 3-D fire growth model also be linked to the fire simulator to demonstrate the spread of fire from a different perspective as well as to observe progression of line building forces versus fire growth. Where in the past simulations were only effective with intermediate levels, experienced students can now participate due to realism and difficulty levels presented by using videodisc technology. It is felt that this level of training would contribute greatly in the recertification process.

The Hinton Forest Technology School, in cooperation with a number of other agencies, is also currently arranging to obtain a videodisc on advanced fire behavior that was orginally designed by Utah Sate University but is being adapted to meet Canadian requirements. This disc will act as a supplement in the training of students using the above-mentioned technology.

TECHNICAL SESSION II:

FIRE RESEARCH PROGRAMS IN SUPPORT OF FIRE MANAGEMENT DECISIONS AND SOLUTIONS

FIRE RESEARCH PROGRAMS IN SUPPORT OF FIRE MANAGEMENT DECISIONS AND SOLUTIONS

OPENING REMARKS

Moderator:

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It is indeed an honor to actively participate, as a session moderator, at the first annual meeting and workshop of the Interior West Fire Council. Yesterday we heard about problems and opportunities in fire management. This morning we will look at some fire research programs designed to support fire management decisions and offer at least partial answers or solutions to pressing problems.

It is my experience that fire research and fire management have, on balance, complemented each other very well. This is not to encourage any sense of complacency but rather to acknowledge the determination and commitment of both researchers and managers to overcome obstacles in their combined effort to solve difficult problems related to the control and use of wildland fire.

I think, however, that the largest challenge yet facing fire researchers and fire managers is the challenge of change. Indeed, in the 1980s we have seen unusually severe fire seasons, not only in Canada and the U.S. but elsewhere in the world as well, notably China, Australia, and unexpectedly, Indonesia, a land of tropical rain forest. Notwithstanding the inherent dangers of speculation I think it is worth considering the implications of ever-increasing severe fire weather, particularly in light of widely publicized and increasingly accepted climate change scenarios. If some of the projections of climate change are only partially accurate, we stand to witness, before the end of the century, unprecedented fire regimes on a global scale.

Is the fire community, researchers and managers, positioned to respond positively and effectively to such change? I believe that we have laid the groundwork to accept new challenges. But more than ever before, fire researchers and fire managers will have to work together with a renewed commitment to each other and the public they serve. Perhaps the measure of a successful program of fire research is the degree to which important problems are *identified* and *agreed* upon by fire managers and fire researchers; the degree to which research *focuses* on these problems and the *efficiency* with which research findings are *transferred* into operations[1].

In the first part of this session, we will hear from four speakers who will discuss research programs aimed at improving wildfire control. We will hear about the relative effectiveness of some of our primary fire control resources, including initial attack crews, fire retardants and aerial delivery systems, and firefighting foams, products receiving considerable recent attention. And finally, we will hear about some new approaches to dispatching fire control resources. In the second part of this session, following the break, four speakers will share with us their research programs that are aimed at improving our knowledge and application of prescribed fire.

THE AUTHOR

DENNIS DUBÉ serves as the National Forest Fire Research Coordinator for the Forest Science Directorate at Forestry Canada headquarters, which is located in Hull, Quebec. Dennis received a B.Sc. degree in wildlife biology from the University of Montana (1966) and an M.Sc. degree in botany (plant ecology) from the University of Alberta (1976). He joined ForCan in 1973 as a Fire Research Officer and from 1980 to 1984 was project leader of the Fire Management Systems and Guidelines Project at the Northern Forestry Centre in Edmonton, Alberta. He spent a year and a half as the Superintendent of Forestry for the City of Winnipeg, Manitoba, before returning to Forestry Canada at its national headquarters in June 1986 in his present position.

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[1] Underwood, R.J. 1985. Research for forest fire operations in Australia. Pages 269-282 *in* J.J. Landsberg and W. Parsons, editors. Research for forest management. Commonw. Sci. Indust. Res. Org., Div. For. Res., Canberra, Australian Capital Territory.

DETERMINING PRODUCTION RATES OF INITIAL ATTACK CREWS

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ABSTRACT

Initial attack crews are a traditional and integral component of most fire control organizations; providing rapid, aggressive suppression capabilities while fires are small. This paper describes the methodology and results of a three-year study designed to assess the production rates of initial attack crews over a range of fuel resistance and fire intensity categories. Eighteen experimental fires were conducted in three major fuel types in central Alberta during the 1986, 1987, and 1988 fire seasons. In addition, two wildfires adjacent to the study area were actioned and documented. Fire behavior was closely monitored from both ground and air, and crew production was measured from time of initial attack through to the time of flame extinguishment over the entire fire perimeter. Crew equipment consisted of Pulaskis, shovels, backpack pumps, and a power saw. Hotspotting production rates ranged from 19 m/person-AA-hour to 403 m/person-hour and were a function of the fire behavior variables and fuel resistance. Topographic variation is minimal in the boreal forest region of Alberta, hence this factor was not considered in our production functions.

INTRODUCTION

Initial attack capability is a fundamental aspect of all fire management organizations, and despite the current technological advances, hand crews remain as a viable traditional component. The production rates of initial attack crews are relevant to attack strategy and tactics, and are particularly useful for dispatch and containment models. A number of published studies present fireline production[1] guidelines based on various fuel type classifications (Hansen 1941; Lindquist 1970; Murphy and Quintilio 1978; Haven et al. 1982; Schmidt and Rinehart 1982). Most of these studies also recognized the effects of other factors such as topography, fire behavior, and crew factors.

The study described in this paper was designed to monitor crew performance in the boreal forest over a range of fire behavior and fuel variables (North American Forestry Commission 1988). Experimental or prescribed fires and actual wildfires provided the realism of initial attack. Generally, in the boreal forest, initial attack involves hotspotting the fire perimeter, with a crew of 3-6 members, supported by a helicopter equipped with a bucket. Hotspotting is defined as a method to check the spread and intensity of a fire at those points that exhibit the most rapid spread or that otherwise pose some special threat to control of the situation (Merrill and Alexander 1987). To date there is only one reference to continuous handline production rates in the boreal forest (Murphy and Quintilio 1978) and none for the hotspotting technique. In 1985, it was deemed a priority by the Canadian Forestry Service and the Alberta Forest Service that handcrew production rates in major boreal fuel types be documented. The present study was implemented and conducted during the 1986, 1987, and 1988 fire seasons. An earlier report[2] and paper (Quintilio et al. 1988) presented the results of the first two seasons, including the methods of data collection.

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[1] Synonymous with "fireguard production" (Merrill and Alexander 1987).

PROJECT STUDY AREA

The study area is located approximately 70 km east of Wabasca, Alberta, (latitude 55°58′ N, longitude 113°50′ E). Upland sites of typical boreal forest stands composed of black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) were selected on the basis of their strategic location in the surrounding muskeg area. The high water table and sparse, noncommercial vegetation of a typical treeless muskeg provided a secure fireguard for a full range of fire intensities. Further descriptions of the environmental and vegetation characteristics in the general study area can be found in Strong and Leggat (1981).

MAJOR FACTORS DETERMINING FIRELINE PRODUCTION

Through literature review and discussions between researchers and fire management agencies, a list has been compiled of the major factors affecting the probability of a crew with hand tools successfully attacking a wildfire (Table 1).

Crew Factors

When planning a fire attack strategy, a fire management agency has control over crew factors. After assessing situation factors, fuel factors, and fire factors, the agency can determine what combination of crew factors is necessary to maximize the probability of successfully attacking the fire.

Table 1. Factors affecting the probability of a suppression crew successfully attacking a wildfire with hand tools

Major categories and specific elements
A. Crew factors
1. Type (e.g., initial attack, helitack, man-up)
2. Size and configuration
3. Training (type and configuration)
4. Physical condition
5. Experience
6. Freshness
7. Attitude and motivation
8. Supervisor and capability
B. Situation factors
1. Attack mode (i.e., initial or sustained)
2. Water availability
3. Topography
C. Fuel factors
1. Fuel resistance-to-control
a. Crown fuels
b. Surface fuels
c. Ground fuels
2. Torching or crowning potential
D. Fire factors
1. Area and perimeter
2. Rate of spread
3. Intensity
a. Flame length/height
b. Heat output
4. Torching and crowning
5. Spotting
6. Smoke

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[2] Murphy, P.J.; Woodard, P.M.; Quintilio, D. 1987. Development of fireline production guidelines for initial and sustained attack for several fuel types. Univ. Alta., Fac. Agric. For., Edmonton, Alberta. CFS-PRUF Contr. Rep. (unpublished).

Situation Factors

The relationships between the situation and crew factors are relatively straight forward. The attack mode (initial or sustained) will dictate the crew type (initial attack or man-up). Water availability will dictate what types of water handling equipment will be appropriate. Topography has little direct effect on fireline production rates for crews with hand tools because the effort required to move uphill is minimal compared to the overall effort required to construct fireline (Murphy and Quintilio 1978). Topography will, however, have indirect influence through its effects on fire behavior.

Fuel Factors

Forest fuels pose a physical obstacle to the construction of fireline. We refer to this as fuel resistance to control. Murphy and Quintilio (1978) developed an index that quantitatively describes fuel resistance to control[3] based on tree height and density, brush height and density, amount of deadfall and slash, duff depth, and occurrence of large stones and roots. This index shows a negative exponential relationship with respect to production rates for continuous handline construction (Fig. 1). A recent simulation study has confirmed this relationship for both initial attack and sustained attack situations (Murphy et al. 1989).

In addition to the physical removal of fuels from a fireline, different fuel types exhibit differences in potential fire behavior. For example, in the boreal forest of central and northern Alberta, torching and crowning occur more readily in black spruce stands than in jack pine stands because of the vertical continuity of fuels in black spruce stands. The importance of torching and crowning will be illustrated in our discussion of fire factors.

Fire Factors

The area and perimeter of an initiating fire and the forward rate at which it is spreading at the time of initial attack will dictate the minimum rate of fireline production necessary to successfully contain the fire (Alexander 1985). Other characteristics of the fire may directly affect how fast fireline can be constructed. As fire intensity increases, the ability of crews with hand tools to directly attack the flaming front decreases, thus decreasing the rate of held-line production[4]. This may be modeled using the negative exponential relationship. Theoretically, at some point, fire intensity becomes so great that it precludes direct attack with hand tools (Alexander and De Groot 1988) and the effective rate of fireline production drops to zero (Loane and Gould 1986). A schematic representation of this proposed relationship is illustrated in Figure 2 using flame length as a direct indicator of fire intensity (Alexander 1982). The extinction point beyond which attack with hand tools is not successful as depicted in Figure 2 may be defined by the flame length at which crowning and spotting begin to occur. This critical flame length will vary between fuel types, being higher for jack pine types than for black spruce types (Alexander 1988).

The amount of smoke produced by a fire will also affect the ability of crews with hand tools to directly attack the fire front. At any given fire intensity, the presence of smoke will reduce the potential fireline production rate (Fig. 2). As fire intensity increases, convection columns may form and carry smoke away from the fire front. When this occurs, the relationship between fireline production rate and flame length reverts to the no-smoke situation shown in Figure 2.

RESULTS AND DISCUSSION

The basic study approach of conducting experimental or prescribed fires provided a unique opportunity to observe and document suppression crew performance under realistic fire conditions. Eighteen simulated wildfires and two actual wildfires near the study area provide the bases for the following results. Table 2 summarizes the data collected over the 3-year period of the present study. A range of fire intensities from low vigor surface fires to intermittent crown fires was achieved during the study period. Three fuel types (open black spruce, overmature black spruce, and open jack pine) provided a range of fuel resistance characteristics.

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[3] Synonymous with *resistant to fireguard construction* (Merrill and Alexander 1987).

[4] Incorporates the concepts of *resistance to fireguard construction* and *difficulty of control* which jointly determine the *resistance to control* (Merrill and Alexander 1987).

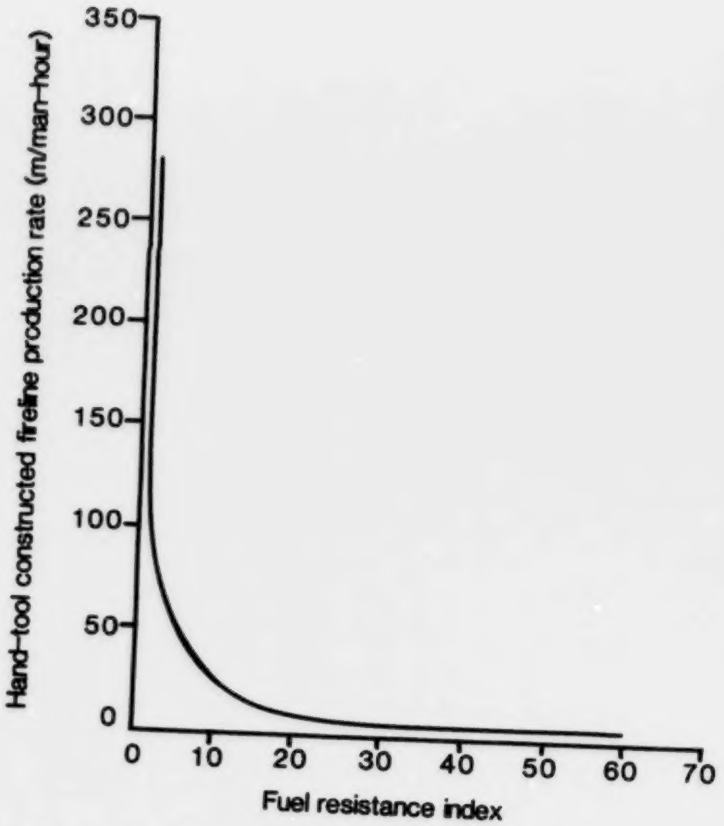

Figure 1. Relationship between hand-tool constructed fireline production rates and the fuel resistance index of Murphy and Quintilio (1978).

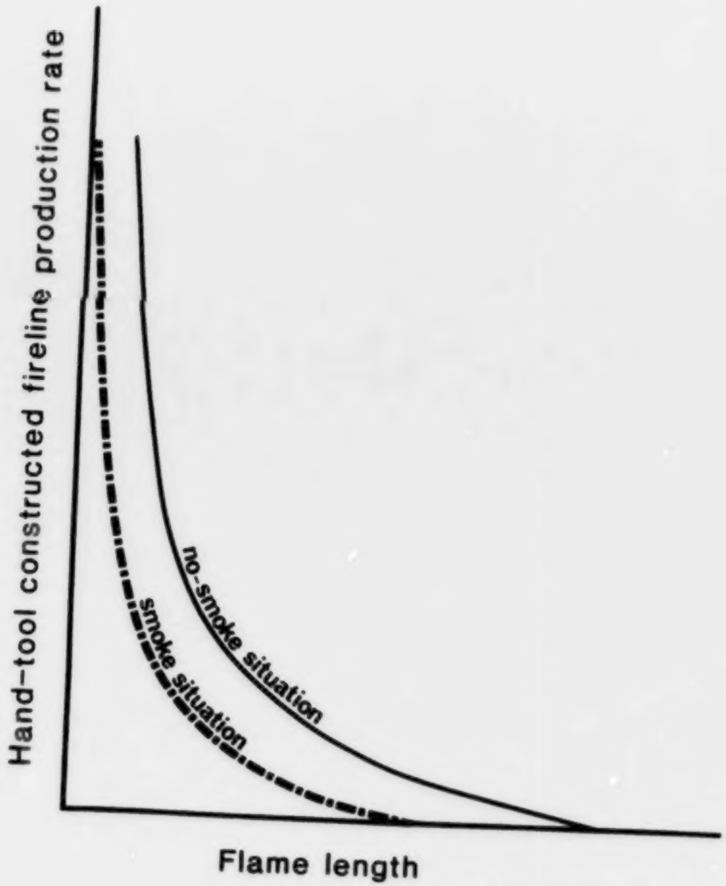

Figure 2. Conceptual relationship between hand-tool constructed fireline production rates and flame length with and without significant volumes of smoke.

Table 2. Attendant burning conditions, fuel and fire characteristics, and crew hotspotting productivity associated with the various fires documented during the Wabasca Project, 1986-88

Fire no.	Dry-bulb temperature (°C)	Relative humidity (%)	10-m open wind (km/h)	Days since rain[a]	Canadian Forest Fire Weather Index (FWI) System components[b]						Forest cover type[d]
					FFMC	DMC	DC	ISI	BUI	FWI	
86-01	27.0	36	15	2	89	21	367	9.0	37	18	A2Pj
86-02	30.0	27	11	3	90	25	375	6.0	42	14	B2Pj
86-03	30.0	28	10	3	90	25	375	6.0	42	14	B+C2Pj
86-04	22.0	54	16	1	83	16	355	3.0	29	6	A2Pj
86-05	27.0	35	14	1	82	18	359	2.5	32	6	A1Sb
86-06	25.0	38	17	2	89	21	367	9.0	37	18	A1Sb
86-07	28.0	31	10	3	90	25	375	6.0	42	14	A1Sb
86-08	29.0	29	8	3	90	25	375	6.0	42	14	A1Sb
DF3-6-86[c]	22.0	27	33	6	87	42	162	15.0	51	30	A0Sb
DS6-36-87	29.0	37	13	3	91	39	531	10.0	64	26	A0Sb
87-20	29.0	26	15	4	89	37	488	8.0	62	21	B1Pj
88-30	26.5	28	24	2	87	24	89	9.0	29	15	C2Pj
88-31	26.0	28	25	3	90	28	97	15.0	33	24	C2Pj
88-32	29.0	23	25	3	90	28	97	15.0	33	24	C2Pj
88-33	20.5	46	22	4	90	31	105	13.0	36	22	C2Sb
88-34	22.0	43	22	4	90	31	105	13.0	36	22	A1Sb
88-35	23.0	48	20	5	89	34	112	10.0	38	19	C2Sb
88-35A	25.0	44	20	5	89	34	112	10.0	38	19	C2Sb
88-36	23.0	39	20	5	89	34	112	10.0	38	19	A1Sb
88-37	19.5	62	12	3	87	35	141	5.0	43	12	A0Sb

Continued on next page

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[a] Amount greater than 0.6 mm.

[b] FFMC = Fine Fuel Moisture Code; DMC = Duff Moisture Code; DC = Drought Code; ISI = Initial Spread Index; BUI = Buildup Index; and FWI = Fire Weather Index. Refer to Canadian Forestry Service (1984) for definitions of the six standard components of the FWI System.

[c] Wildfires. The remaining fires were carried out on an experimental or prescribed basis.

[d] Coded according to Alberta Forest Service Phase III Inventory maps: crown density, stand, height, and species composition. Crown density classes: A, 6-30%; B, 31-50%; C, 51-70%; and D, 71-100%. Stand height classes: 0, 0.0-6.0 m; 1, 6.1-12.0 m; and 2, 12.1-18.0 m. Species composition: Pj = jack pine and Sb = black spruce.

Table 2. Continued

Fire no.	General fire behavior characteristics					Head fire			Production rate (m/person-hour)
	Creeping	Running	Candling[e]	Crowning[f]	Spotting	Spread rate (m/min) Average	Spread rate (m/min) Maximum	Flame length (m)	
86-01	no	yes	no	no	no	2.8	4.0	0.33	242
86-02	no	yes	yes	no	no	1.3	5.0	0.44	342
86-03	no	yes	no	no	no	0.6	5.0	0.33	403
86-04	yes	yes	no	no	no	1.0	1.5	0.33	230
86-05	no	yes	yes	no	no	1.5	2.0	0.75	156
86-06	no	yes	yes	yes	yes	3.3	6.0	1.00	164
86-07	no	yes	yes	yes	no	2.1	5.0	2.00	364
86-08	no	yes	yes	no	no	2.2	5.0	1.50	246
DF3-6-86[c]	no	yes	yes	yes	yes	8.0	30.0	3.00	19
DS6-36-87	no	yes	yes	yes	yes	2.5	–	1.00	106
87-20	no	yes	yes	no	no	1.0	2.0	0.25	192
88-30	no	yes	no	no	no	1.2	1.7	0.50	328
88-31	no	yes	no	no	yes	2.7	4.0	1.25	175
88-32	no	yes	no	no	no	2.7	4.0	1.40	235
88-33	no	yes	yes	yes	yes	7.5	12.0	7.50	45
88-34	no	yes	yes	no	no	1.4	3.0	4.00	123
88-35	no	yes	yes	no	yes	5.0	10.0	8.50	70
88-35A	no	yes	yes	no	yes	5.0	7.0	2.50	94
88-36	no	yes	yes	no	yes	2.0	4.0	3.50	133
88-37	no	yes	yes	no	no	1.4	3.5	1.75	401

[e] Synonymous with *torching* (Merrill and Alexander 1987).

[f] Limited to intermittent crown fire activity (Merrill and Alexander 1987).

Hotspotting production rates ranged from 19 m/person-hour to 403 m/person-hour using a standard initial attack crew equipped with Pulaskis, backpack pumps, and a power saw. Figure 3 illustrates the relationship of fireline production against four different variables using simple linear regression for all fires in the spruce and pine fuel types. Some of the variation in the regression lines in Figure 3 can be attributed to differences in fuel type characteristics, the natural variability in fuel and stand characteristics between plots even within the same broad cover type, and the inherent difficulty of occularly estimating flame lengths due to the transitory nature of active fire fronts. Additional analysis is currently underway using multiple regression techniques which will address the combined effect of the variables influencing fireline production. These results will be presented as a final chapter on the Wabasca Project.

The best production was achieved in the jack pine cover type, where flame length, rate of spread, and fuel resistance were the lowest. Production rates were based simply on the effort required to extinguish surface flames and the time required to walk the perimeter of the fire. The most effective tool was a backpack pump for spraying water.

Production slowed in the open black spruce cover type as flame length and rate of spread increased, and a power saw was needed to remove standing trees near the fire perimeter. Since candling and torching is a certainty in this fuel type, the role of the power saw operator was critical during the flanking action.

The lowest production rates were achieved in the overmature black spruce cover type which exhibited significant quantities of down-dead woody fuels. The crews actually reverted to parallel attack to avoid the radiant heat associated with the intense surface fires. Again the power saw was essential and the Pulaskis were used extensively to supplement the saw work and to build a scratch line. The backpack pumps effectively controlled the surface flank fire as it burned into the constructed handline.

CONCLUDING REMARKS

In summary, much was learned about initial attack crew production. The use of experimental or prescribed fires is certainly a relatively new and effective approach for assessing fireline productivity. Production ranges are significant in relation to the fire and fuel parameters and should be carefully evaluated during initial fire assessments. Modelers beware—there is as much production variation as fire behavior variation!

ACKNOWLEDGMENTS

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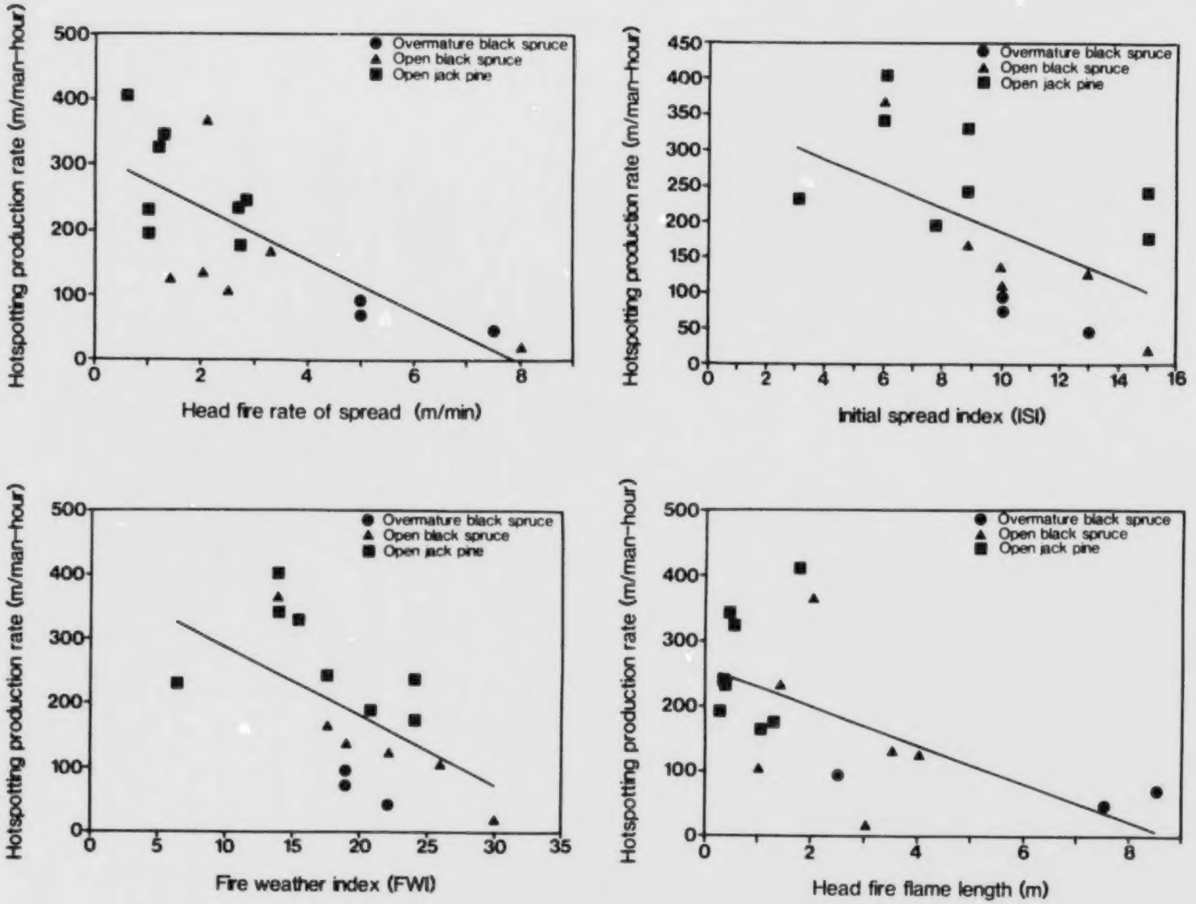

Figure 3. **Linear trends between hotspotting production rate of initial attack crews and four different variables derived from the experimental fires and wildfires documented during the Wabasca Project.**

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AN UPDATE ON THE OPERATIONAL RETARDANT EFFECTIVENESS (ORE) PROGRAM

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ABSTRACT

To determine how much chemical or retardant is needed to do a given fire suppression job and to relate those amounts to fuel and fire behavior characteristics, a major cooperative Operational Retardant Effectiveness (ORE) study was undertaken. A pilot study at Hemet in southern California in 1983 demonstrated the feasibility and value of the approach conducted under actual operational conditions. This study was expanded and operated for full fire seasons from Hemet in 1984 and 1985 and from Redding in northern California from 1986 to 1988. Temporary operations were also conducted in Redmond, Oregon, during 1985. The high fire activity during 1985 and 1987, with less than normal to normal activity occurring in the other years, provided excellent research opportunities. Some study results were implemented operationally in near real time and other results were incorporated in training at various levels, in contract specifications, and in national or interagency criteria. Considerable data were used in ongoing retardant and delivery research and development programs. This paper presents the status of the Operational Retardant Effectiveness (ORE) study, discusses the expanding and changing objectives, and provides examples of study findings and spin-offs.

WHAT IS THE ORE STUDY?

Numerous studies have quantified aspects of aerial fire suppression (George 1981, 1984). Some studies were theoretical, some were conducted in the laboratory, and others were conducted under controlled field conditions to simulate certain aspects of retardant application. Although most of these studies have provided insight into specific parts of the overall problem of aerial delivery and suppression of wildland fires, they have not simultaneously integrated the many influencing variables into one scenario. Although the need for this integration under actual field and use conditions can be argued, the credibility and acceptability of results to fire personnel involved in the application of wildland fire chemicals are obviously enhanced. As the name implies, the ORE study is an "operational" evaluation of the effectiveness of wildland fire chemicals applied from aircraft. Initially planned to concentrate on fixed-wing application, the study was later expanded to include helicopter use. In both instances, the operational nature of the study allowed for both the observation of the various application tactics and strategies and the effectiveness of various types of wildland fire chemicals, including water, foam, and long- and short-term retardants.

To determine how much chemical or retardant is needed to do a given fire suppression job the pilot study sought to do the following:

1. Identify methods, techniques, and criteria for the evaluation of on site retardant effectiveness in actual fuel and fire conditions.
2. Determine the retardant concentration requirements for specific fuel models in fire situations, and validate or refine, if necessary, retardant coverage levels prescribed in retardant coverage decision aids.
3. Evaluate the accuracy and usefulness of the existing decision aids in selecting the optimum drop conditions, for example, height, speed, tank configuration, and drop sequence.
4. Identify delivery system characteristics that provide the most efficient control of drop performance and patterns in actual fuel and fire situations.
5. Develop appropriate guidelines and training for the effective application and management of aerial retardant.

The approach to conducting the study under operational conditions consisted of aerial evaluation of the entire suppression operation, evaluation by a ground team who traveled to the site by helicopter when the opportunities and situation allowed, and documentation of the condition under which the aerial application occurred, using onboard aircraft instrumentation. The California Department of Forestry and Fire Protection (CDF) supplied a fixed-wing aircraft. The aerial observation team consisted of two people: an evaluator who was qualified as an air-attack supervisor and an equipment operator. Onboard equipment included FLIR (Forward Looking InfraRed) capability, a video camera, and video recorders. Video signals from the cameras as well as operational and intercom-evaluation comments provided a permanent record of the operation and evaluation. The ground evaluation team consisted of a fire behavior analyst, an experienced line fireman, and a retardant research specialist.

The helicopter specialist was experienced as a line fireman and normally participated in the evaluation. He also operated a video camera documenting the actions of the ground evaluation team, the fire behavior, suppression operation, and aerial suppression application. The ground evaluation team took fire behavior measurements and appropriate fuel and fuel moisture samples. Estimates of the retardant ground pattern distri-butions, including retardant coverage, were made. A postmortem, when possible, helped determine the effective retardant coverage level. Postmortems were made by selecting appropriate fuel samples to which retardant had been applied such that the retardant was effective in stopping or minimizing the fire spread. The fuel samples were returned to the laboratory for analysis, and the effective retardant coverage level was determined.

To provide definition of the retardant release characteristics and drop conditions, instruments were installed in the locally based air tankers and sometimes in additional air tankers (George 1982). The equipment consisted of a high-precision pulse radar altimeter system, which provided a continuous record of the drop height during a pass, and an airspeed transducer to record airspeed. The electrical circuit from the door-opening system was used so that signals to the door-opening solenoids were recorded, providing the exact time of door opening, time interval between releases, and thus the drop configuration for any release sequence. Self-contained velocity gravity height (VGH) recorders from the National Aeronautics and Space Administration were also installed on the air tankers selected for instrumentation. These recorders provided additional information, including time-history records of aircraft speed, altitude, and acceleration during the mission. The VGH records also provided a history of the mission's flight duration, time to first drop, dash speed to first drop, rate of descent, maneuver acceleration fraction, drops per mission, maximum airspeed, and time from drop to touchdown. Video cameras were also installed on the sun screen of the air tankers when practical. The cameras provided a video coverage of the general approach to the target, the topography, the fuel, and fire behavior. Radio communications and intercom talk between the pilot and copilot were recorded on one of the audio channels of the video tape.

Miscellaneous other data were considered essential or especially valuable in documenting the mission effectiveness. These included information regarding the fire retardant qualities for each drop or mission. On completion of the retardant loading operation, a sample of retardant was taken from the fill line. This sample provided a record of the type of retardant being used and was later analyzed to provide the actual retardant salt content and viscosity, which could have a significant effect on the effectiveness of a drop. The sample was also used as a check in situations where a question about the retardant quality arose, such as lack of color or volume, excessive drift or low viscosity, or ineffectiveness in retarding combustion. Other data included the use of postfire information from interviews of operational air-attack personnel, air tanker pilots, lead-plane pilots, ground personnel, or others having firsthand knowledge about the incident. Dispatch records, fire reports, and other records were also used to supplement evaluation data.

ORE STUDY OBJECTIVES

The ORE (operational retardant effectiveness) study sought answers in quantitative terms that could lend themselves to more in-depth analysis to fill knowledge gaps. Study areas concentrated on relating effective retardant coverage and fuel and fire characteristics; tailoring the chemical or retardant to the need; optimizing tank and gating system performance; and developing adequate use guidelines for air tanker selection, allocation, deployment, and real-time use.

In the course of the ORE study, other significant questions and needs arose, leading to modifications in the original study design. Some of the more important changes included the following:

1986 - Conceptual evaluation of the use of wildland fire foam from fixed-wing aircraft
- Operational evaluation of two new long-term fire retardant formulations (Fire-Trol LC-A and LC-S)

1987 - Pilot study aimed at determining the operational effectiveness of helicopters (using methods, procedures, and instrumentation from the ORE study):
  - using wildland fire foam, water, or chemical retardants; and
  - providing input for continued development of a helicopter delivery simulation model

1988 - Emphasis on conceptual evaluation of wildland fire foam delivered from either helicopters or fixed-wing aircraft
- Operational evaluation of a new concept in variable flow delivery from fixed-wing aircraft (Aero-Union SP-2H)
- Operational evaluation of a new long-term fire retardant formulation (Fire-Trol PS-F)

ORE DATA COLLECTION

Although all fire seasons since 1983 have been fairly productive, the majority of the data were collected during the 1985 through 1987 seasons, as illustrated in Table 1. Complete numbers of observations are not available for 1988 nor are certain types of information for earlier years, such as helicopter data (primarily video/FLIR) for the years prior to emphasis on evaluating the aerial suppression capabilities and effectiveness of helicopters.

ORE STUDY FINDINGS

Research Methods, Procedures, and Instrumentation

One of the initial concerns in conducting the ORE study was whether meaningful data could be collected under actual operational conditions given the logistics of the problem, the number of previously unquantified variables, and the necessary subjectivity of the evaluation of the effectiveness of tactical applications that resulted from the interrelationship of method of attack (i.e., indirect as a strict retardant or direct as an extinguishing agent) and the resulting effectiveness. Early study results demonstrated that the instrumentation developed and perfected, the methods and techniques used, and the analysis procedures had many practical applications. The onboard air tanker instrumentation developed to document the performance of the air tanker and the conditions under which the drops or retardant applications were made proved crucial to the evaluation. The video and FLIR recordings provided invaluable documentation for training and operational applications, which will be discussed in a later section. Study results showed the ability to move a ground evaluation team to necessary locations in near real-time.

Table 1. Summary of basic operational retardant effectiveness (ORE) study data, 1983-88

Item	Year						6-y total
	1983	1984	1985	1986	1987	1988	
Months ORE active	1.8	2.2	2.7	3.0	4.3	3.8	17.8
Number of fires							
ORE data	9	25	42	69	112	73	330
Helicopter data	—	—	—	—	55	42	97
Number of observed drops							
Total	15	189	299	363	1168	729	2763
Fixed-wing	15	189	299	354	629	450	1936
Helicopter	—	—	—	9	539	279	827

Air Tanker Performance Guides

The performance of air tankers as described in existing air tanker performance guides and retardant coverage computer/slide charts has been partially validated. Estimates of performance and effect of primary parameters, such as drop height, drop configuration, and retardant type (waterlike or gumlike) have been demonstrated to be adequate. The advantage of using increased drop heights in many instances to provide more uniform and efficient retardant distributions has been confirmed. The value of using gum-thickened retardant to minimize evaporation and drift during operational use (especially when winds normally associated with difficult fire behavior are encountered) has been substantiated under operational conditions. The importance of drop interval in sequential drops was shown to have a major and often limiting effect on the resulting pattern—especially continuity. Manual or inappropriate drop intervals frequently caused patterns to contain gaps and allow retardant line to be ineffective, which resulted in inefficient coverage levels and was extremely unreproducible. As a result of these early findings, intervalometer requirements were proposed to the Interagency Air Tanker Board (IATB). The proposed standards were accepted and have been incorporated into IATB mandatory requirements and agency contract specifications.

The value of variable flow rate, and hence coverage level, has been similarly demonstrated and proposed for inclusion in standards and requirements. One of the spin-offs of the ORE study associated with air tanker performance is quantification of the operational envelope under which air tankers are operated. Although the use of data collected onboard air tankers to study the operational use aspects was secondary, the opportunity to gain knowledge on this facet of use exists. An example of such a situation and data can be shown regarding the C-119 aircraft. As a result of recent accidents with the C-119 (the latest during the 1987 fire season in northern California) and questions concerning conditions under which these aircraft have been operated, a quick analysis of a portion of the drop condition data was made. VGH data from several seasons of use from a C-119 showed that maximum drop airspeeds set forth in the supplemental type certificate for the C-119 and *g*-loads of 2.5 *g* (that are interrelated) are frequently being exceeded during fire control operations (Figs. 1-4). Specifically, maximum drop speeds were exceeded over 90% of the time, and 2.5 *g* were exceeded on more than 25% of the drops. Although this problem cannot be addressed simply, the data certainly have implications to air tanker operations. It is difficult to keep airspeed down in much of the steep terrain where downslope runs are required. The data, however, assist in defining operational flight conditions and suggest a number of additional questions that should be addressed:

1. If the C-119 cannot be operated within the prescribed envelope, should it have been used as an air tanker?

2. What efforts or steps did operators and agencies take to attempt to keep airspeeds within the appropriate flight envelope? Was this covered in training? If not, why?

3. Can this type of data be used by the IATB or individual agencies to evaluate the suitability of new or existing aircraft?

4. Do similar situations exist for other types of currently used aircraft?

Helicopter Water and Foam Delivery

The pilot study initiated in 1987 was aimed at determining the operational effectiveness of helicopters and whether procedures developed during the preceding ORE study to accomplish a similar objective with fixed-wing aircraft was applicable. Results in 1987 and 1988 indicate that subjective results are obtainable. The same degree of quantification with helicopters is currently not possible for two reasons. First, the instruments required to document the operational flight envelope and the delivery performance of the water or retardant release system (usually a bucket) have not been developed. Secondly, the pattern of use and the situations in which helicopters are used are often unstructured and unpredictable. The general effectiveness of helicopters has been subjectively evaluated, and their effectiveness in support of helitack or other ground suppression activities has been clearly documented. The use of foam from helicopters is quite valuable depending on the tactical use, fuel, fire behavior, and application conditions. The greatest benefits were obtained when direct fire attack was being made in close support of ground suppression activities. Foam properties can have a significant effect on the foam's effectiveness, that is, dry foams do not penetrate overstories well and can detract from their ability to penetrate heavy ground fuels. There is also a need to differentiate between long-term retardants that can be used effectively for indirect

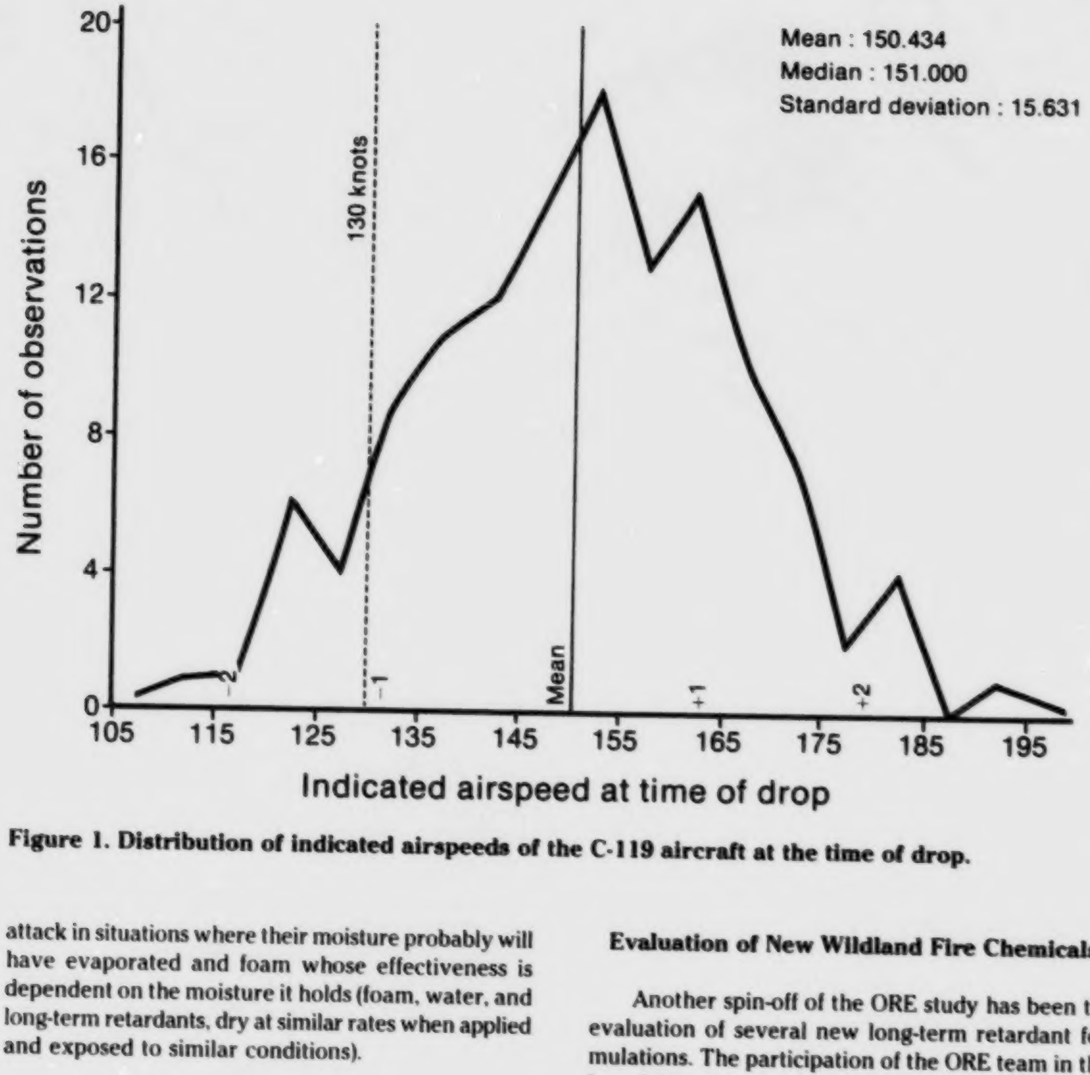

Figure 1. Distribution of indicated airspeeds of the C-119 aircraft at the time of drop.

attack in situations where their moisture probably will have evaporated and foam whose effectiveness is dependent on the moisture it holds (foam, water, and long-term retardants, dry at similar rates when applied and exposed to similar conditions).

The use and effectiveness of helicopters and fixed-wing aircraft are obviously different. The ORE study has many examples illustrating the effectiveness of both helicopters and fixed-wing aircraft under different conditions and tactical applications. These tools clearly are different, and their use needs to be evaluated differently. It is not appropriate to compare their costs or effectiveness in most situations unless careful and quantitative comparisons of their suppression productivity are included.

Evaluation of New Wildland Fire Chemicals

Another spin-off of the ORE study has been the evaluation of several new long-term retardant formulations. The participation of the ORE team in this has depended on such factors as location of the selected retardant base and how the new formulation differs from existing products. The capabilities of the ORE team have resulted in coordination of field evaluations with the ORE study and use of evaluation procedures, instrumentation, and personnel. Examples of coordinated efforts were the evaluation of new formulations, Fire-Trol LC-A, LC-S, and Fire-Trol PS-F and the conceptual evaluation of wildland fire foams. As a result, Fire-Trol LC-A and Fire-Trol PS-F have satisfied evaluation requirements and have been approved

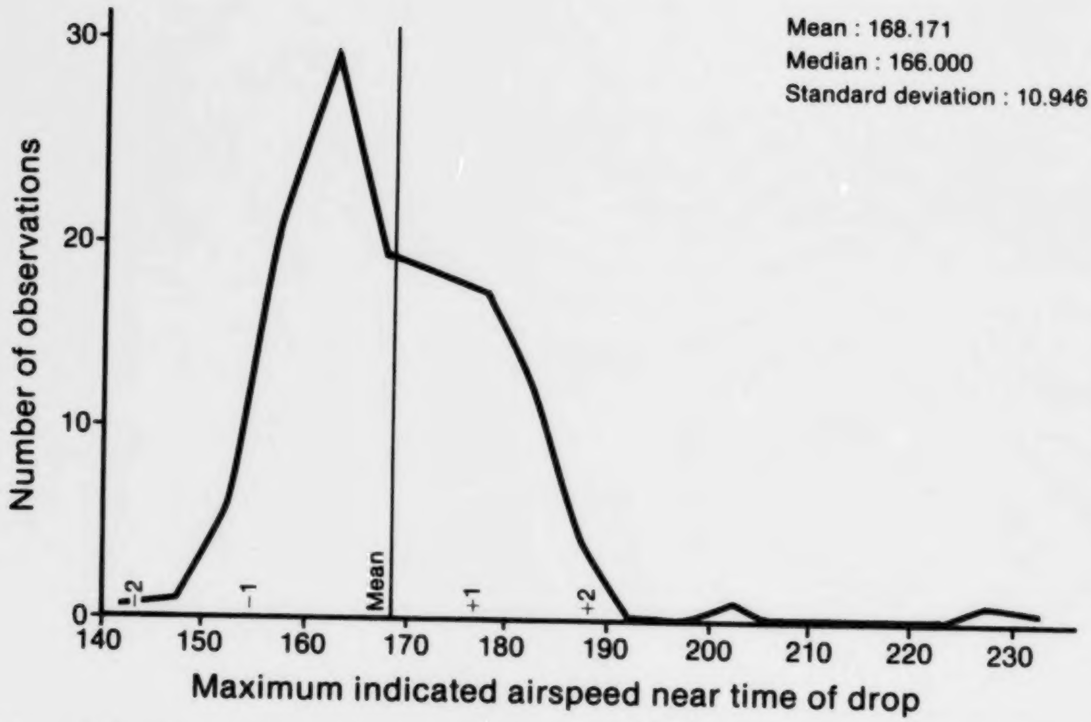

Figure 2. Distribution of maximum indicated airspeeds of the C-119 aircraft near the time of drop.

for operational use. Likewise, four wildland fire foams for use from helicopters using buckets and one from helicopters using fixed tanks have been approved.

A conceptual evaluation of the use of wildland fire foam from fixed-wing aircraft (in addition to the evaluation from helicopters, previously discussed) was initiated late in the 1986 season and continued through 1987 and 1988. Results have indicated that foams can be effective when applied from fixed-wing air tankers in direct attack situations on lower intensity fires, especially in the support of ground suppression personnel. Use in and around structures, vehicles, and improvements can have related advantages compared to alternatives involving chemicals and coloring agents that often require special post-suppression clean-up activities. Fixed-wing aircraft using foams have a narrow "use" window as compared to those using long- or short-term retardants. Increased drop speed and especially drop height, as well as wind, can have a very deleterious effect on foam delivery, and low drop heights do not provide the time needed for foam to develop.

Results also indicate that distance and time required for the breakup and development of foam is not significantly different (as thought) from normal aerially delivered retardant nor substantially safer as far as ground personnel are concerned. Also, characteristics of specific fixed-wing delivery systems greatly influence the efficiency of foam development and distribution patterns. When considering the properties of the foam itself, the wet foams (and lower expansion) are more effective than dry foams. Dry foams are intercepted to a greater degree by aerial vegetation and are more easily dispersed by wind. The retention of dry foams by the aerial portion of the fuel, even in grass, has allowed fire to burn underneath the moisture that is being held above by the foam.

One of the needs identified in the foam evaluation is the need for performance standards for mixing

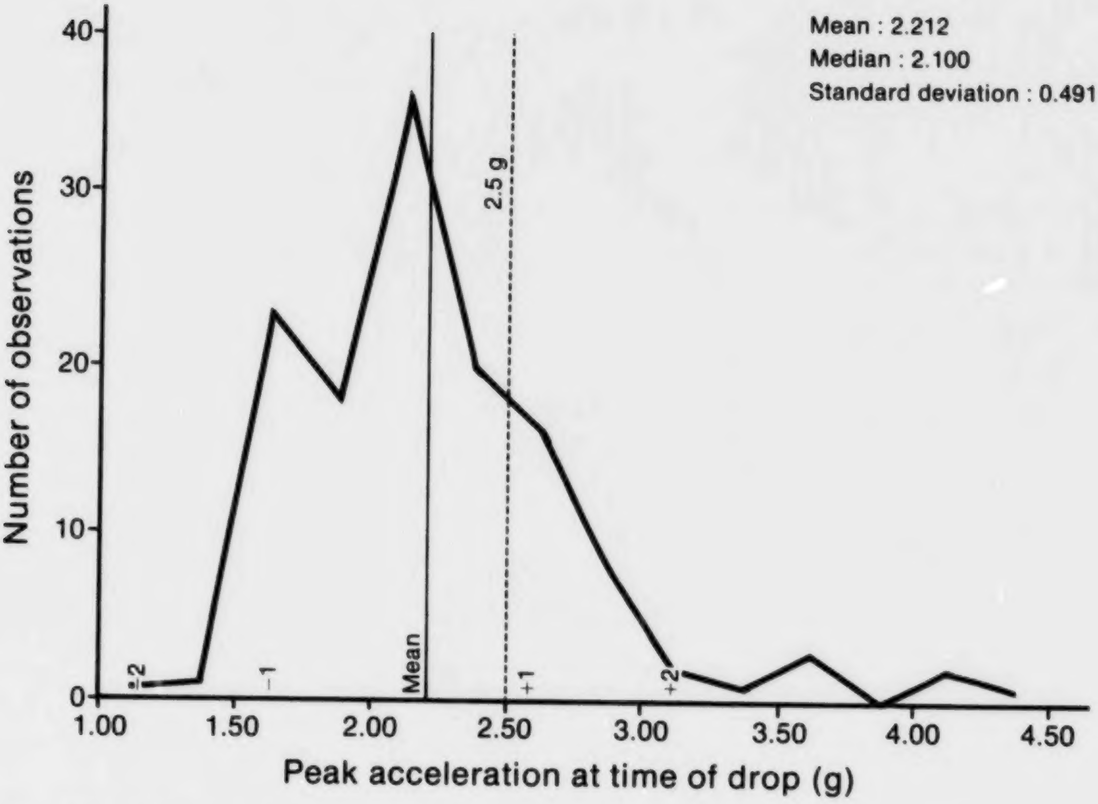

Figure 3. Distribution of peak accelerations at the time of drop from the C-119 aircraft.

and injection and storage and handling of the foam concentrate. Numerous problems in early developed hardware indicate a number of shortcomings; these included lack of precision in concentrate ejection; inadequate mixing; handling and mixing that allowed contamination; and inadvertent ejection and return-flow of the foam concentrate.

A key factor is the practicality of using foam in fixed-wing aircraft intermittently with long-term retardant. Efficient use of foam and any advantage offered depend on the tactic being used, the fire suppression situation, and logistical ability to make chemical selections in a real-time situation (i.e., to change between using foam and long-term retardant).

Retardant Effectiveness

Less than anticipated progress was made toward quantitatively relating the effective retardant requirement with fuel properties and fire behavior. The majority of observations have been in light fuels, although some observations have been made in nearly all of the U.S. fuel models used for predicting fire behavior. Results to date, however, have verified the current recommended coverage levels by fuel model as reasonable estimates or rule-of-thumb for effective retardant coverage, although more accuracy is needed to improve efficiency and provide quantitative input to tailored retardant formulations, optimized delivery

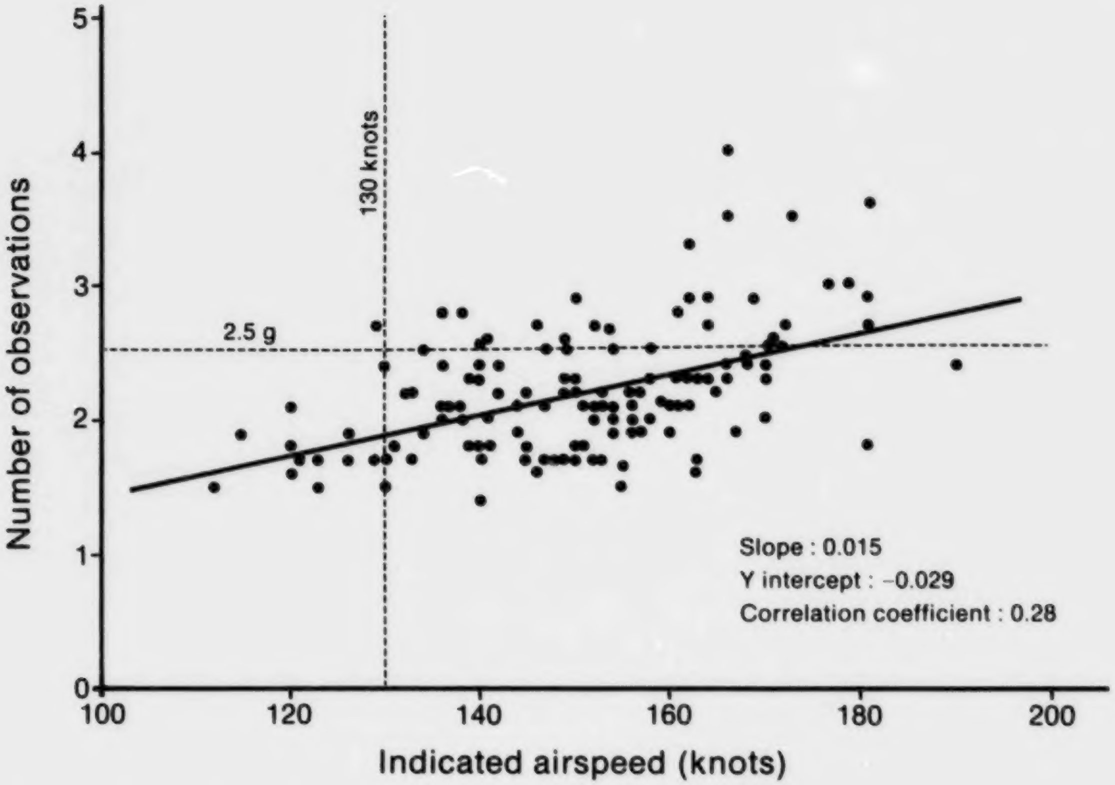

Figure 4. Distribution of drops in relation to the 130-knot maximum airspeed and 2.5-g peak acceleration criteria.

system design and flexibility, and use guidelines to encompass various planning and real-time needs.

The effective retardant levels for given fuel models depend on fire-line intensity or flame length and can vary as much as 800% (e.g., 0.5 g/cm to 4.0 g/cm for Fuel Model A [grass]). The variability with the fuel models currently used contributes largely to variation in fire-line intensity and effective coverage relationships. Until more definitive fuel and fire behavior models are developed, improvements to recommended retardant coverage levels will likely be limited. Further analysis of the existing ORE data will undoubtedly provide additional and more quantitative results in this and other areas of study.

Management

It might be beneficial to point out a couple of observations from the ORE study:

1. Aerial fire suppression (using fixed-wing aircraft and helicopters) can be extremely effective; however, poor management can quickly overshadow gains made in chemicals, delivery systems, and application guidelines.

2. Use of FLIR by air attack supervisors can be easily demonstrated to have major payoffs in terms of improved fire suppression capability and efficiency. Numerous examples can be shown

where information easily provided by use of FLIR on a single incident could be projected to pay for the cost of an FLIR unit and its implementation.

Further analysis of existing ORE data and incorporation of results into standards and guidelines will undoubtedly provide substantial benefits.

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EFFECTIVENESS OF FOAM AS A FIRE SUPPRESSANT

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ABSTRACT

This paper gives an overview of the history of forest fire fighting foam, foam characteristics, criteria critical to product selection, the benefits of using foam, and the results of effectiveness trials and evaluations.

INTRODUCTION

The addition of substances to water to enhance the water's fire suppression characteristics was first studied extensively in the 1930s. Although numerous additives were identified as beneficial, the logistics of using these products in concert with the available equipment proved impractical. During the ensuing years, technological changes in forest fire suppression facilitated the development and use of retardants and suppressants. The additives were basically of three types: those that made water more viscous; those that chemically improved the water; and those that produced foam. Agents that made water more viscous have come and gone. Chemically altered water, i.e., as a long-term retardant, is currently widely used. Water in the bubble state (i.e., foam) is currently gaining wider acceptance.

Foam is an aqueous agglomeration of bubbles that are separated from each other by a liquid film. The main constituent in this liquid film is water. The bubble cavities are filled with air. A 1% foam having an expansion of five times has the following volumetric proportions: air, 80%; water, 19.8%; and chemical additives, 0.2%. If the expansion is 15 times, then the proportions are as follows: air, 93.3%; water, 6.6%; and chemicals, 0.1%. The chemical make-up of the foam concentrate may contain water and, therefore, the net volume of chemicals per unit volume is indeed small.

Energy balances among constituents making up this bubble structure determine the stability of the foam. Structural rearrangements from spheres to polyhedrons take place until some semblance of an energy balance is reached. The binding forces are due to the presence of surface-active agents (surfactants), which facilitate the formation of foam and permit the foam to retain its bubble structure. The diversity of the solubility of components making up the surfactant is responsible for the decrease in surface tension of water and for its foamability.

HISTORICAL OVERVIEW

The research community has been studying foam for decades to determine which additives improve the fire-fighting characteristics of water. Forestry Canada pretty well stayed on the sidelines until the 1960s, at which time research was undertaken internally by employees and also by contractors. Their main objective was to produce a satisfactory foam in the presence of 2% mono- or di-ammonium phosphate and to test its use in the field. This meant searching out existing agents that would fulfill this need. Research by Forestry Canada was terminated around 1970 for lack of any major breakthrough. The foams that could be generated using existing products had too high an expansion rate and lacked the stability required for forest fire use. In the ensuing years attention was focused on convincing people in industry that there was a potential for marketing a slow-draining low-expansion foam agent to the forestry sector. These overtures met with little success for nearly a decade until Lorcon Incorporated of Ottawa expressed an interest. This interest led to the development of SILV-EX, which was first used operationally in 1985.

Preliminary Evaluations

First aerial tests with formulations prior to developing SILV-EX were conducted in New Brunswick in 1982. Air tanker drops made on grass, slash, and standing timber were used to identify product weaknesses. It turned out that the mix ratio and foam expansion were too high and the drainage rate of the foam was much too fast. The formulation that emerged in the marketplace (SILV-EX) in 1985 was used operationally on wildfire in British Columbia and experimentally in France, Corsica, and Spain. The overseas tests permitted us to evaluate the CL-215 as a foam generator, to determine the coverage of and canopy penetration by the foam, to identify aerial delivery limitations, and to determine the foam's worth as a suppressant. The following conclusions were made:

1. The foam does an excellent job of enveloping the fuels compared to water.
2. The foam not only coats the fuels but it also adheres well.
3. The CL-215 is a good foam generator and it delivers a stable foam that remains on the fuel for an extended period of time.
4. The foam isolates the fuel particles from oxygen and impedes combustion.
5. The foam acts as a much better heat sink than water and reduces the impact of impinging radiant energy.
6. The bubble structure impedes the rate of water evaporation.
7. The foam acts as a surfactant as it reverts to the fluid state, and runoff is reduced because the release of water is gradual. Hence it has a better opportunity to wet the fuels.
8. The white foam is very visible and it acts as a drop marker for air crews.
9. The foam acts as a marker for mop-up crews, i.e., hot spots exist only where total breakdown of the foam is detected.
10. The foam-treated fuels do not seem to rekindle as readily as those treated with plain water.

The question "how much better than water" was never answered, however. Several foam drops were made at the airport in Pembroke, Ontario, to get specific drop pattern data later the same year. The idea of using foam for forest fire suppression had come of age, and its acceptance as a suppressant is now history.

FOAM CHARACTERISTICS

Water is noted for its extraordinary cooling properties, but its use in extinguishing fires is limited by its low viscosity, limited blanketing capabilities, and poor reflectance characteristics. The conversion of liquid water into a stable bubble structure is an attempt to overcome these shortcomings. The amount of water that adheres to a fuel particle depends on its surface roughness. During aerial application the contact time of falling water with the fuel's surface is short; consequently, all excess liquid drains off. Foam, on the other hand, is influenced by surface roughness at the moment of contact, but the surplus may not drain off. The total that adheres is dependent on the foam's structure and bubble stability. The amount of water trapped in the bubble structure may be several times greater on a per-unit-area basis than if liquid water was applied. This is particularly true if bridging occurs between particles. The change in flow characteristics overcomes liquid water's low viscosity, and the change in structure improves water's blanketing capabilities (Fig. 1). This schematic assumes equal amounts of water per unit surface area and a foam expansion of 10 times. The foam provides good blanketing, and its brilliant whiteness acts as a reflective surface.

Dispersion and Mixability

One of the least known or the least publicized facts about foam concentrates is that they do not disperse instantaneously when added to water without agitation. Although their specific gravities range from 1.015 to 1.038, the material has a tendency to settle to the bottom of the tank. The result is that most of the active ingredients end up in the bottom third of the container of water. This occurs irrespective of the temperature of the water or its salinity level. The drainage curves in Figure 2 confirm excessive settling in warm water and also in cold water (Fig. 3). Saline water may entrap the concentrate at the water's surface and cause it to settle to the bottom slowly. Sampling prior to completion of transferring concentrates will reveal an enriched upper layer (Fig. 4) and an enriched lower layer within a container of water. The "well stirred" curve represents the foam developed using a homogeneous solution.

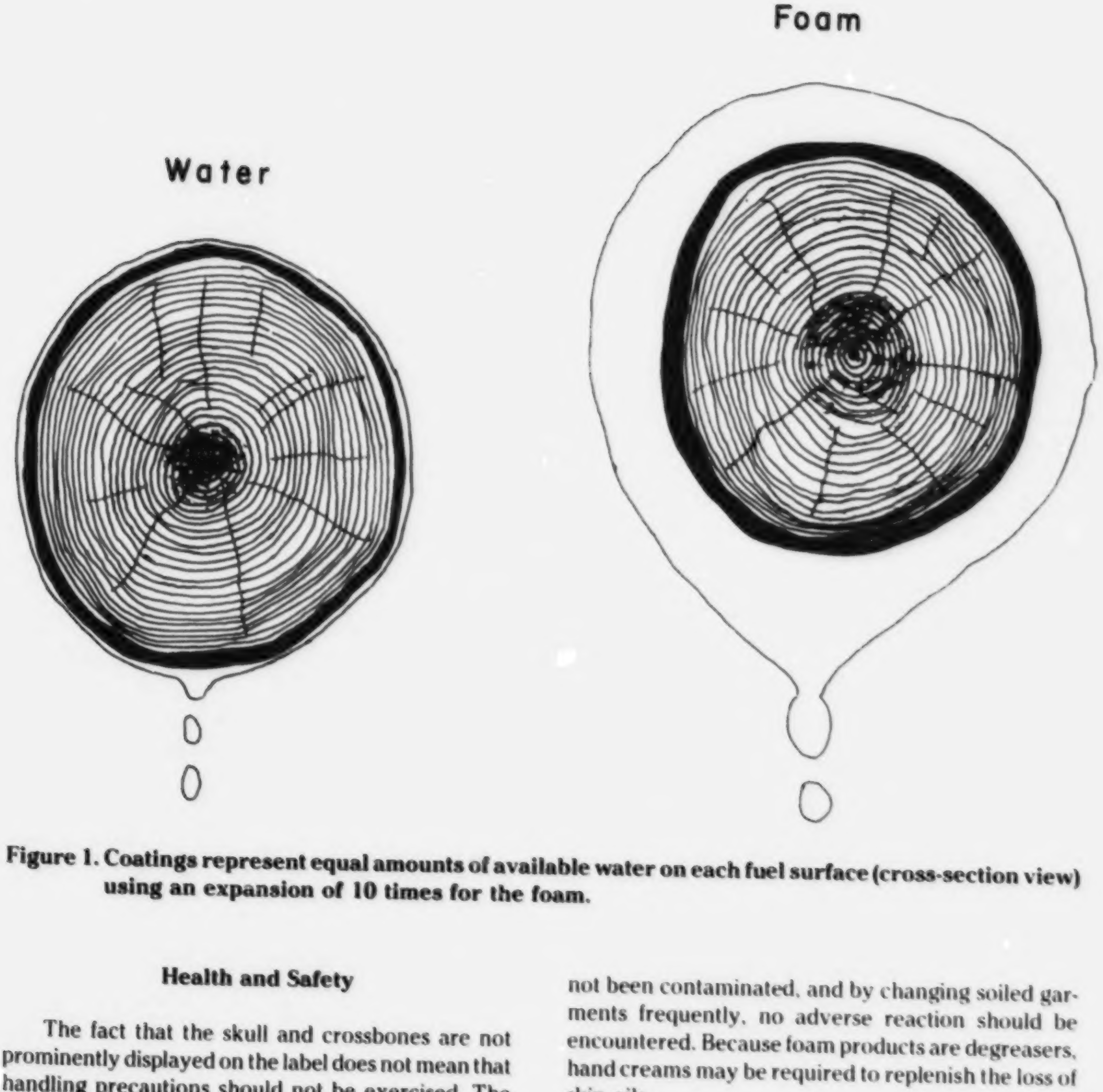

Figure 1. Coatings represent equal amounts of available water on each fuel surface (cross-section view) using an expansion of 10 times for the foam.

Health and Safety

The fact that the skull and crossbones are not prominently displayed on the label does not mean that handling precautions should not be exercised. The chemicals that make up the foam-generating agents smart the eyes much the same as shampoo. Ingestion of these products will result in diarrhea, which may require medical attention depending on the quantity consumed. Prolonged exposure may affect those with very sensitive skin. By practicing good hygiene, ensuring that the water used for human consumption has not been contaminated, and by changing soiled garments frequently, no adverse reaction should be encountered. Because foam products are degreasers, hand creams may be required to replenish the loss of skin oils.

Environmental Considerations

Policies concerning environmental issues are developed and enforced by provincial agencies. Consequently, the stance taken by each agency concerning

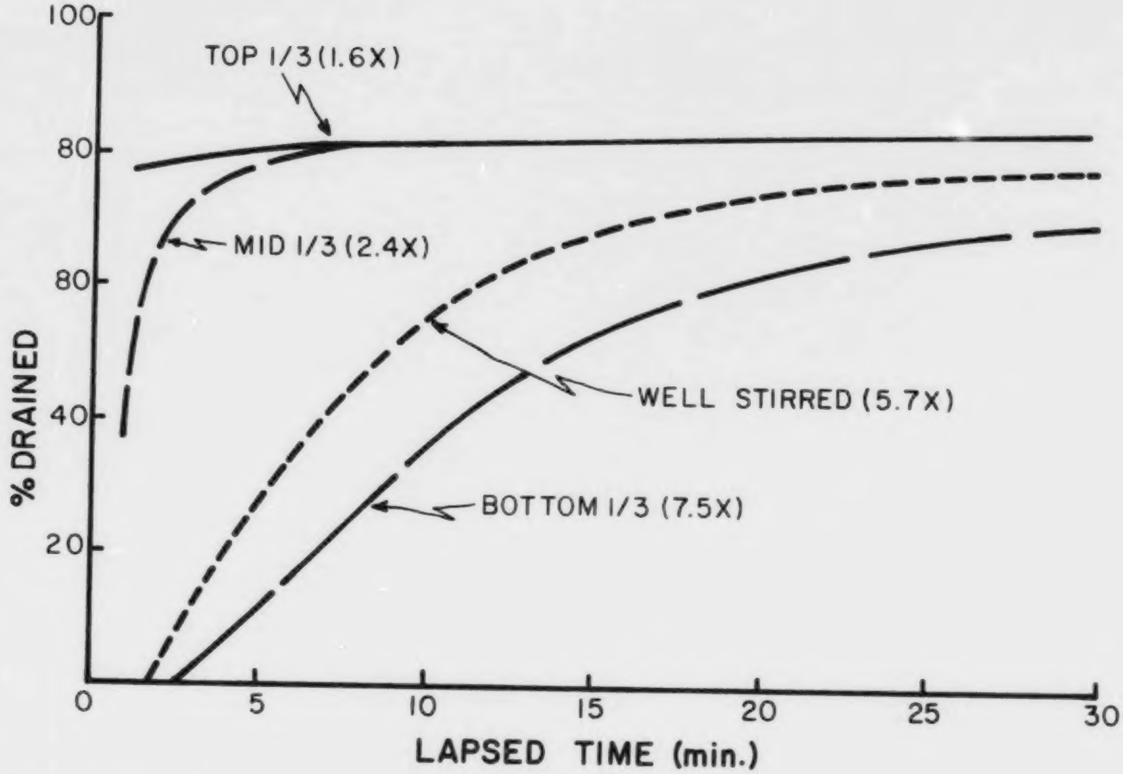

Figure 2. Effect of non-agitation on dispersal of foam concentrate added to distilled water having a temperature of 23.5°C in comparison with a well-stirred 0.65% solution.

acceptable levels of discharge and contamination is different. The question is: "Should the populace be concerned about wholesale use of foam in the natural environment when the use of herbicides and pesticides is tolerated"? The rate of biodegradability of foam constituents is likely much more rapid, and the end products are for the most part naturally occurring products. Above all, the level of application and the percentage of concentrate used in these solutions is low. Industry will respond and reformulate if its products prove unacceptable to any agency. Foliar damage to vegetation from topical applications, based on trials conducted at the Petawawa National Forestry Institute (PNFI), proved insignificant if the vegetation got rained on occasionally. Conifer seedling mortality occurred, however, when the plant roots were continually fed with a foam solution. Contamination of water bodies should be avoided at all cost because the surfactants interfere with the ability of aquatic life to extract oxygen.

Expansion

Expansion has little relevance to the characteristics of the foam that is produced as long as it remains low. Each foam generator has its own limitations. A given percentage of foam concentrate will therefore yield a foam having a different expansion. The curves in Figure 5 are indicative of the diversity of expansions for different generators using a 1% solution. The Dromader M-18 flying at 166 km/h produced foam

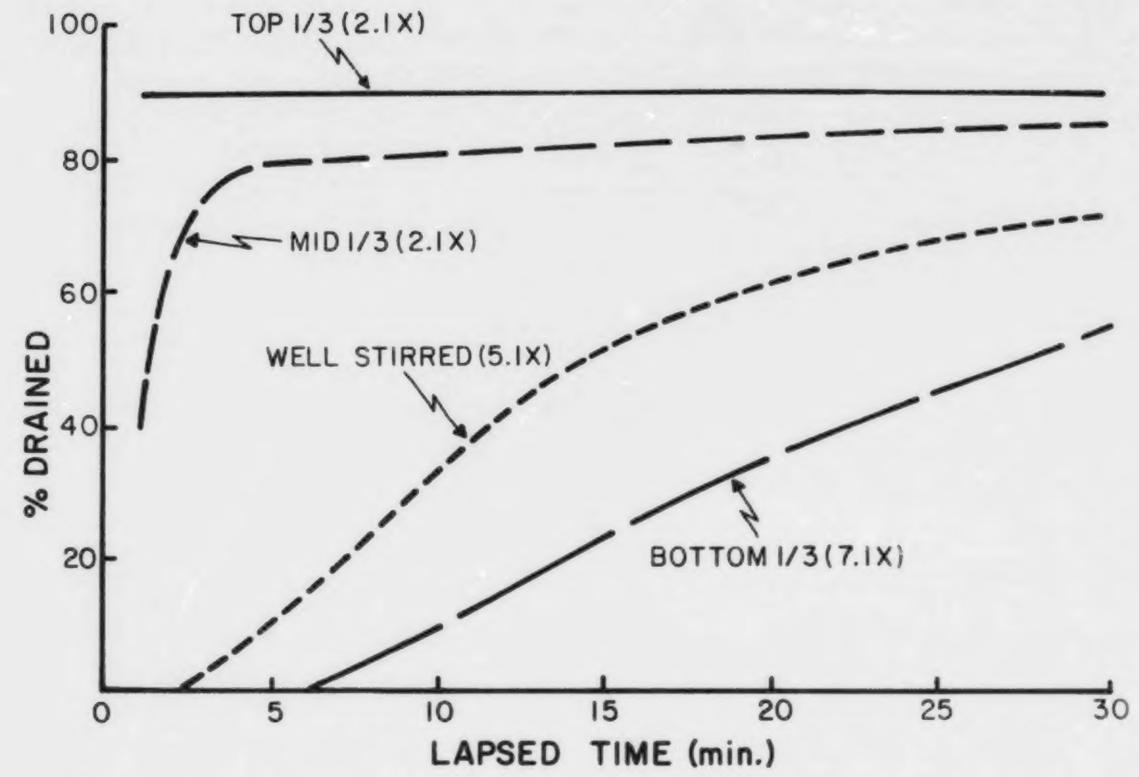

Figure 3. Effect of non-agitation on dispersal of foam concentrate added to distilled water having a temperature of 12°C in comparison with a well-stirred 1% solution.

having the same drainage as the PNFI laboratory compressed air system, yet the M-18-generated foam expansion was more than three times as high. The CL-215-generated foam and the blender-generated foam had the same drainage characteristics, but expansion was 11.3 for the former and only 5.4 for the latter. Foam produced by the M-18 drained faster than the CL-215 generated foam. The foam generated by the WAJAX Mark III pump system using a CO-SON MF-16 foam nozzle drained even faster than the air tanker foams, and its expansion was 17 times. These results indicate the lack of correlation between expansion and drainage characteristics. The stability of the bubble structure cannot be assessed using expansion information.

Drainage and Foam Life

The important factor in assessing foam quality is drainage. The rate of drainage gives a time-related reference to the location of the fluid that is released from the bubble structure. Fuels are wetted by this free liquid. A regulated release rate is therefore most desirable. In defining the optimum liquid release rate it is necessary to consider where the foam comes to rest and what happens to it with time. In a multistoried fuel structure, drainage must be accelerated if adequate wetting is required near the ground to stop the spread of a surface fire below the canopy. In such situations a lower mix ratio is required to promote more-rapid drainage.

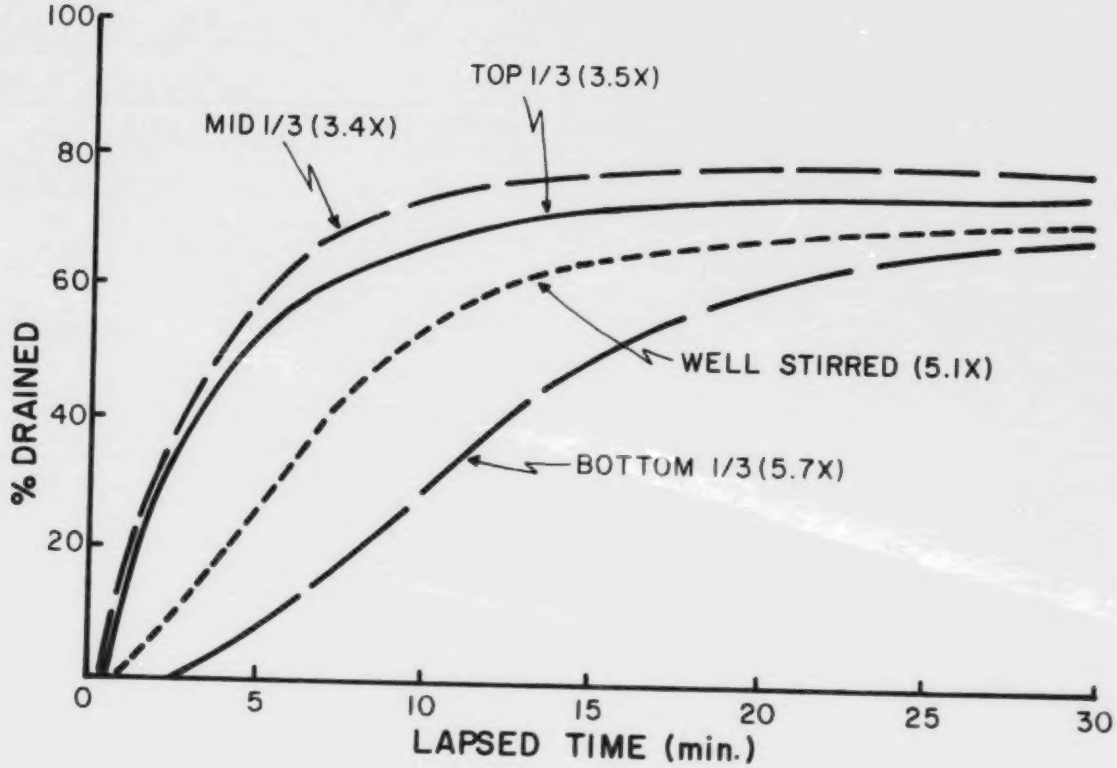

Figure 4. Effect of non-agitation on dispersal of foam concentrate added to salt water having a temperature of 12°C in comparison with a well-stirred 1% solution.

Drainage characteristics essentially tell you whether the foam remains relatively stable for some duration upon landing. The stability of the foam will determine how fast or slow the water filters down to wet the fuel at the lower levels. The drainage characteristics assist the user in determining the mix ratio required for a given generating system to meet a specific need. The curves in Figure 6 reflect the rate of drainage for foam produced by the WAJAX Mark III pumping system using a WAJAX nozzle. Not only do the curves identify that this nozzle cannot effectively utilize the extra concentrate fed into the system beyond the E setting, they also identify how much fluid still remains locked in the bubble structure at any given time following application.

Product Selection

The foam concentrates are not markedly different from each other in terms of the quality of the foam they produce, but some differences may be significant for any particular user's situation. One very important characteristic that must be considered is the viscosity of the concentrate. If these products are used at temperatures above 30°C there is little need for concern, but as the operating temperature decreases, changes in viscosity cannot be ignored. The temperature-viscosity relationships (Fig. 7) vary according to product brand. This increase in viscosity means that as the resistance to flow increases, the pumping, metering, and induction rates will decrease. Product

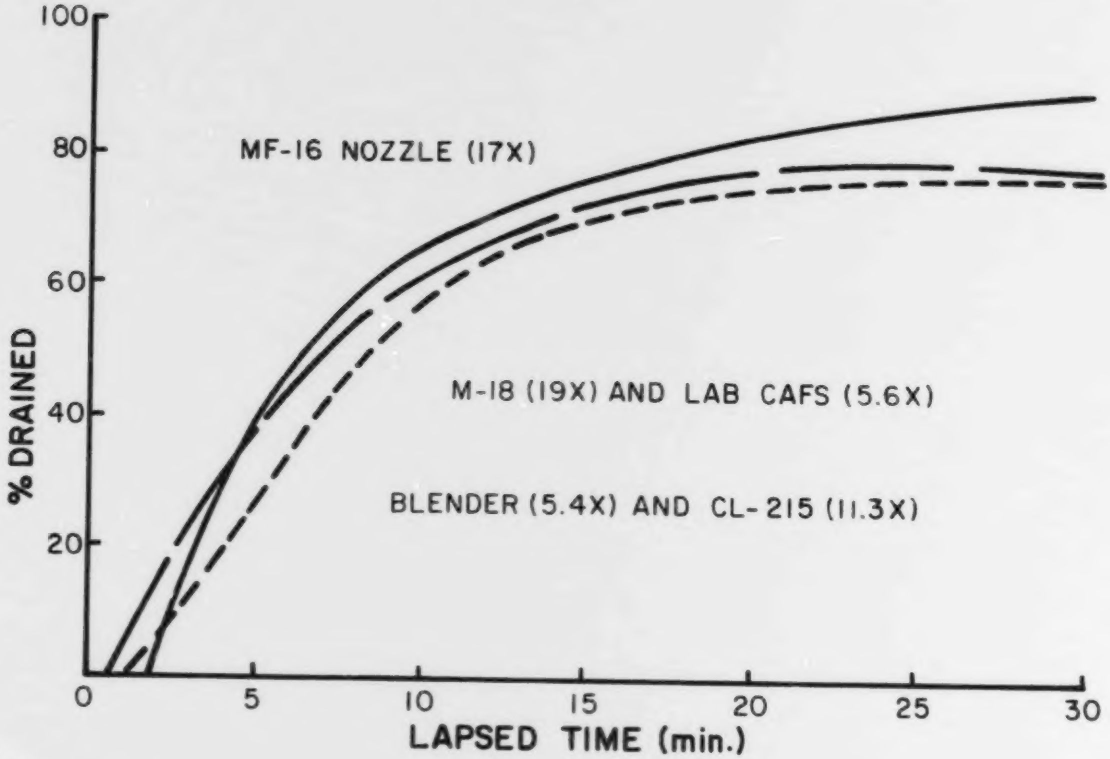

Figure 5. Drainage and expansion comparisons for 1% foams generated by different systems.

brands 'A' and 'B' are least affected by cooling from 30°C to 3°C. Although their viscosity values doubled, the pumping rate decreased by only 15%. Brand 'C', on the other hand, thickens significantly: a fourfold increase in viscosity resulted in a 60% decrease in pumping rate. Brand 'D' was most susceptible to chilling, and its flow characteristics changed drastically at temperatures below 15°C. The important thing to remember is that pumping or injection times must be adjusted as concentrate temperature declines if foam quality is to be maintained.

The next logical concern is how water temperature affects the foam's drainage rate. The standard drainage curve in Figure 8 was arbitrarily selected as representative of a slow-draining foam suitable for forest fire suppression (i.e., a foam that would adequately wet the fuel it contacts and would also drip off and wet fuels at lower levels). The mix percentages were varied for each brand until the curves in Figure 9 were defined to represent the percentage of each product required to maintain the specified drainage-time relationship over the water temperature range of 3-24°C. It is evident that water temperature has an affect on foam stability. The decrease in percent drained during the first 15 minutes for one of the brands is shown in Figure 10. Because the percentage required decreases with declining temperature, the user can elect to forego any adjustments in the mix ratio.

A more important consideration concerning water is its salinity level. All brands of foam are negatively affected by dissolved salts. The extreme case would be the use of sea water. Foams generated using saline waters drain much faster than freshwater foams (Fig. 11). There is a definite need to compensate for the diminution of foam quality when sea water is used.

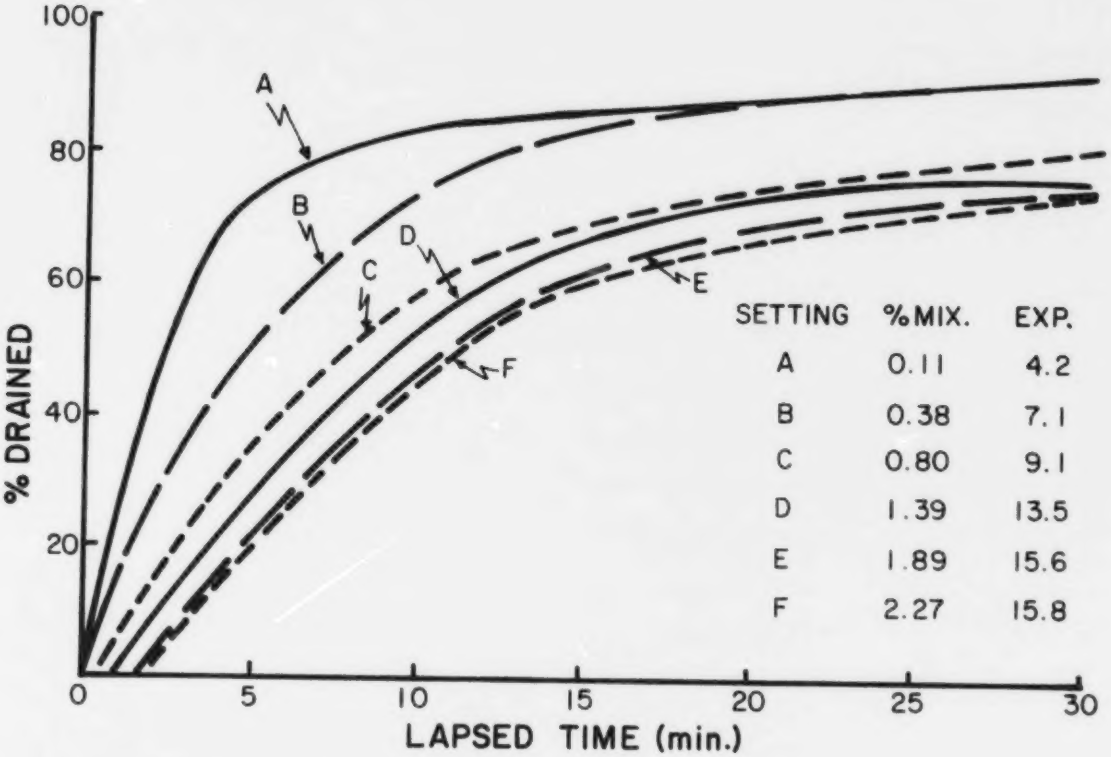

Figure 6. Drainage characteristics of foam generated by a WAJAX Mark 3 pumping system with a WAJAX foam nozzle for Fleck Bros. metering device setting A to F.

The level of dissolved chemicals must be much higher than is found in hard water before any adjustments in mix ratio are required for inland water sources.

Overwintering of foam concentrates should not pose any problem provided the liquid is recycled in spring to ensure homogeneity. Samples of four brands were freeze-thaw cycled 10 times with drainage runs executed after each cycle. There was no change in the drainage rates (Fig. 12). Storage should be in plastic containers or plastic-lined containers because contact with metal reduces the concentrate's ability to generate foam. Exposure to air induces evaporation and crystallization of some products. Ordinary venting of storage containers does not permit enough of an air-vapor interchange to affect the foam concentrate. Limited exposure to air results in an 18-36% loss depending on product brand. Unrestricted exposure to air results in the formation of a semifluid to crystalline state.

BENEFITS OF USING FOAM

Water is water whatever its form so why then use it in its foam state? The conversion of the liquid to a bubble state imparts new characteristics and enhances others to give "expanded water." This form has superior suppression qualities. These enhanced or acquired values are as follows:

1. It insulates the fuel. The pathway through a bubble mass is made up of the fluid in the bubble skins and air within these bubbles. There, the air cells

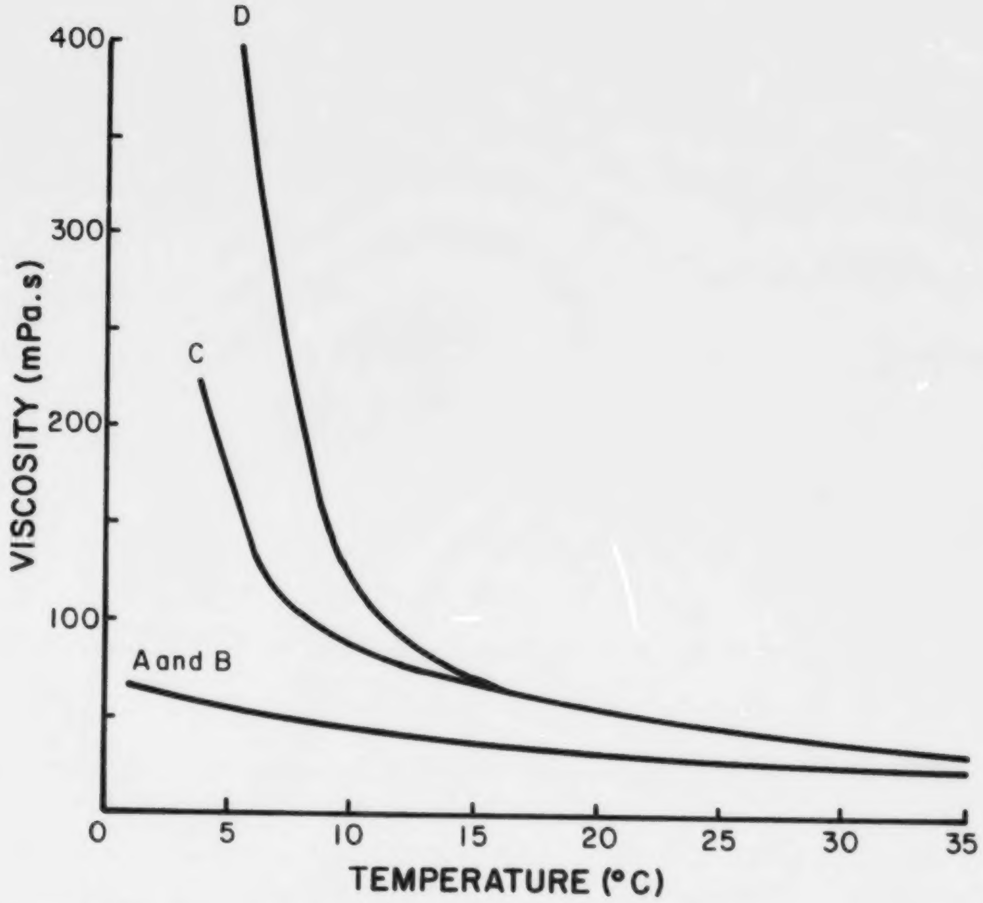

Figure 7. Foam concentrate viscosity-temperature relationship.

act as pockets of insulation. Radiant energy becomes highly diffused when it strikes the foam.

2. It acts as a heat sink. Energy impinging on the foam is diffused by the bubble structure and preheating is not localized. The energy is dissipated laterally, and the potential for rekindling or ignition is lessened.

3. It excludes air. Live coals readily vaporize off sufficient water to permit entry and mixing of oxygen-enriched air with volatiles from glowing embers. The result is rekindling of fuels and a return to flaming combustion. The foam blanket, on the other hand, acts as a durable barrier for a limited time. It dissipates energy, retards burn-through, and impedes entry of oxygen-enriched air to the combustion site.

4. It modifies the microclimate at the fuel's surface. Vaporized water at the fuel interface is trapped by the foam layer, and air pockets in the fuel's proximity attain high relative humidities. The foam impedes free air exchange and the replacement of moisture laden air with dry air.

5. It modifies the microclimate within a stand. Foam breakdown (i.e., conversion from bubble to liquid

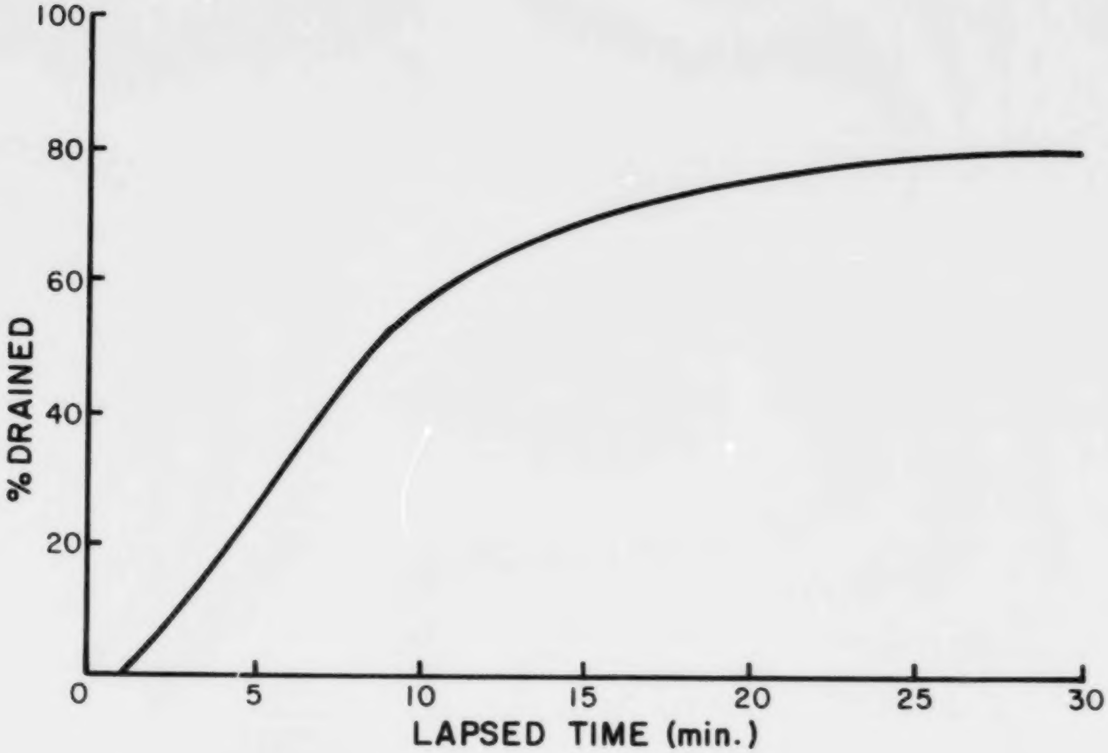

Figure 8. Drainage curve selected as a standard curve for comparing products.

state) at a controlled rate sets up a steady drip (almost a drizzle) that elevates the relative humidity of the air within the forest stand.

6. It wets the fuel more effectively. The surface-active agent in the foam reduces the surface tension of water from 72 dynes/cm to less than 33 dynes/cm. A drop of water in pure form sits on a dry surface like a marble, but, with the addition of a surfactant, this same volume of water will flatten out and spread over a much larger area on this same surface. Wetting agents enhance the water's ability to wet and to penetrate porous materials. Only a thin film of water adheres to a fuel particle depending on surface roughness, and the balance that strikes this surface drains off. Foam stops where it lands and regulates the release of fluid to wet the fuel surface and to penetrate it. The result is more-efficient wetting.

7. It drains at a controlled rate. The rate at which the bubble structure releases water and breaks down is dependent on the mix concentration and the efficiency of the foam generator. The more uniform the bubble structure, the more stable the foam. Bubble uniformity, mix percentage, and exposure to sunlight and wind determine how fast the fluid is released. By releasing the fluid slowly, liquid water is made available for a longer period of time to wet the fuel.

8. It envelops the fuel. On coming to rest on fuel particles, the excess foam does not drain off instantaneously like water but flows gradually, thereby enveloping the particles.

9. It penetrates fuel complexes. Water travels along the path imposed on it by the acting forces i.e., gravity and those imparted to it by the delivery vehicle. These same forces act on the foam, but

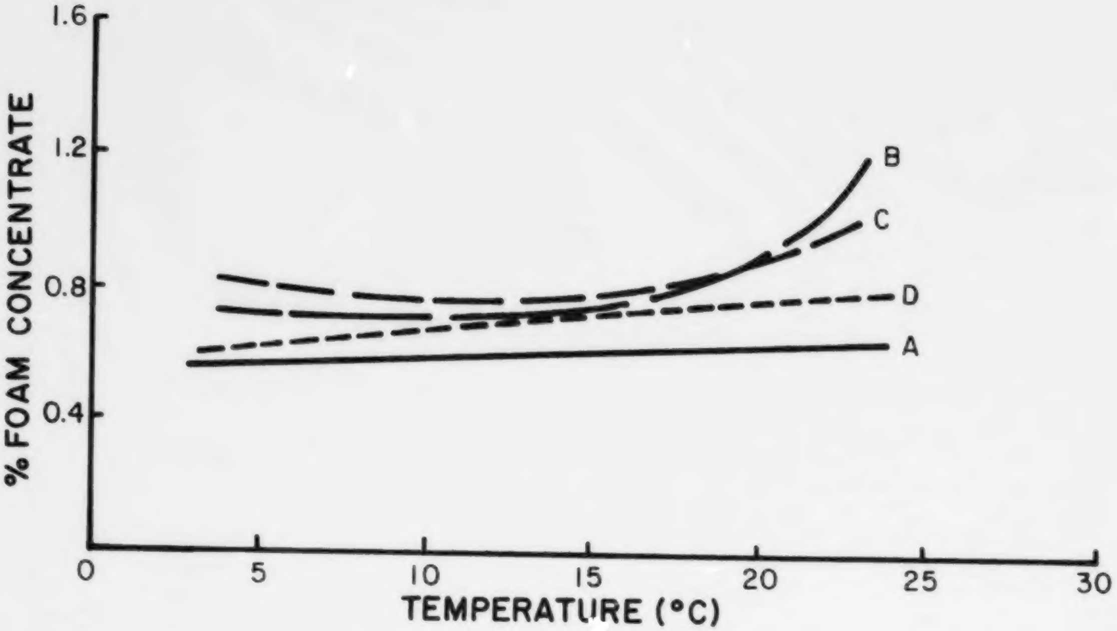

Figure 9. Mix percent required to overcome effect of water temperature and to maintain the same rate of drainage for all product brands.

because of the foam's buoyancy, imposed or induced air movement will alter the foam's descent path. Foam dropped into a canopy has a tendency to drift around and penetrate through openings to envelope fuels that might otherwise not be wetted.

10. It isolates volatile substances. The enveloping of fuels by foam results in an isolation of the volatilization of fuel from the surrounding air. The foam essentially seals in volatile substances and interferes with their combustion.

11. It dilutes volatile substances. These substances, evolving from fuel particles coated with foam, are diluted with the water vapor that builds up at the fuel interface due to absorption of heat by foam. The result is a moisture-enriched gaseous mixture that has a greatly altered ignition threshold, i.e., ignition temperature is elevated.

12. It adheres to fuels. The amount of water that lands on a fuel particle may be many times the amount that actually adheres to the fuel's surface. Foam has flow characteristics unlike those of water. Thus, much more water can be held by the bubble structure per unit area of fuel surface. An increase in amount means more available water for wetting and more available to absorb heat.

13. It increases the amount of available water. Nonwetting (waxy type) surfaces shed water, but when foam is applied, foam adheres to waxy surfaces and wets them via the wetting agent. Vertical surfaces intercept very little water even if they are receptive to water, but in the foam state a substantially greater amount of water can be entrapped.

14. It is visible. Fuels treated with water are difficult to discern from untreated; however, an application of foam is clearly visible for long distances from both the ground and the air. The white is visible against all background colors. This improved visibility aids in better tie-in of air tanker drops and increases the overall attack and mop-up efficiency.

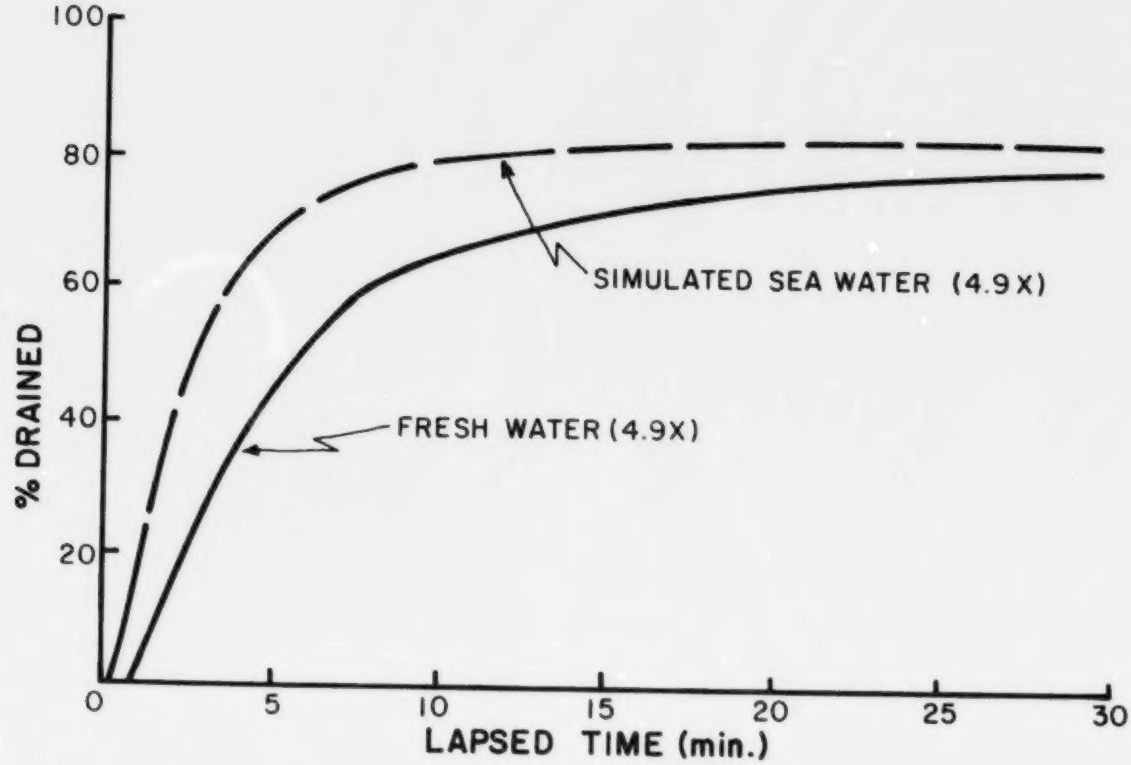

Figure 10. Foam drainage rate difference due to water temperature for 0.6% solution.

15. It inhibits rekindling. In essence, the combination of foam benefits identified in above numbers 1-4, 6-8, and 10-13 inclusive are collectively responsible for the foam's enhanced suppression qualities. The energy released at the combustion interface is dissipated, and cooling takes place.

Together with increased wetting of the combustible fuel, the inhibiting factors reduce the potential for rekindling. Rekindling only takes place where the energy output exceeds that needed to totally dissipate the foam cover. Hot spots that burn through the foam require further suppressive action, whereas all others will suffocate given time.

CONCLUDING REMARKS

The discussion thus far has dealt only with the many factors responsible for enhancing the effectiveness of water when it is bound up in bubble structure. Various claims have been made on how much more effective foam is compared to water, but this information has never been backed up with firm data. Our experience has been that data collection is hampered by over-application, i.e., the amount of foam that was applied exceeded the requirement for the intensity of the particular fire's edge. To determine the critical balance point between go/no-go of the fire's front to the application level, a series of test burns were

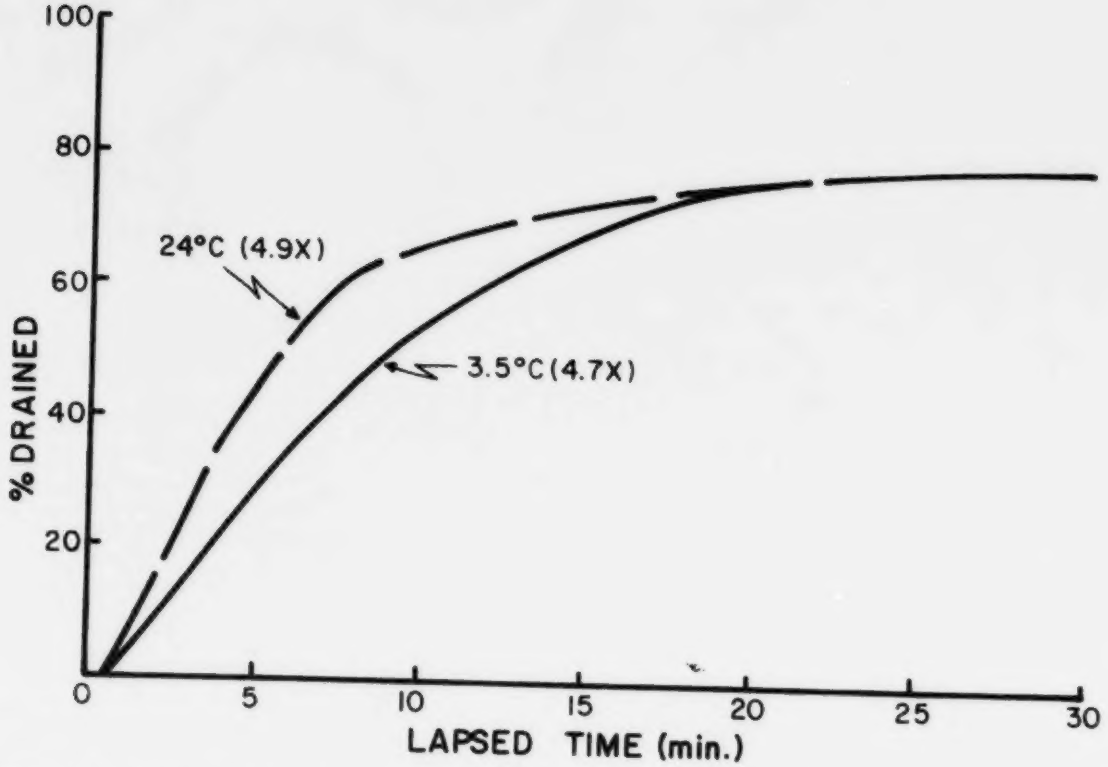

Figure 11. Foam drainage rates using fresh and simulated sea water (0.6% solution at 24°C).

conducted in the laboratory at the Petawawa National Forestry Institute. The results thus far indicate that fires in porous fuel beds (i.e., slash beds with visible openings throughout the full depth of the bed) required 28% less water in the foam state than in the liquid state. Beds that formed a continuous mat, such as balsam fir slash beds, did not permit the foam to coat particles through the entire bed depth, and the requirement to suppress fires in these beds was the same for water and foam. The rate of fire spread was drastically reduced, but under-burning propelled the fire along. It was obvious that the benefits of using foam depended on encapsulating the fuel particles with the bubble mass.

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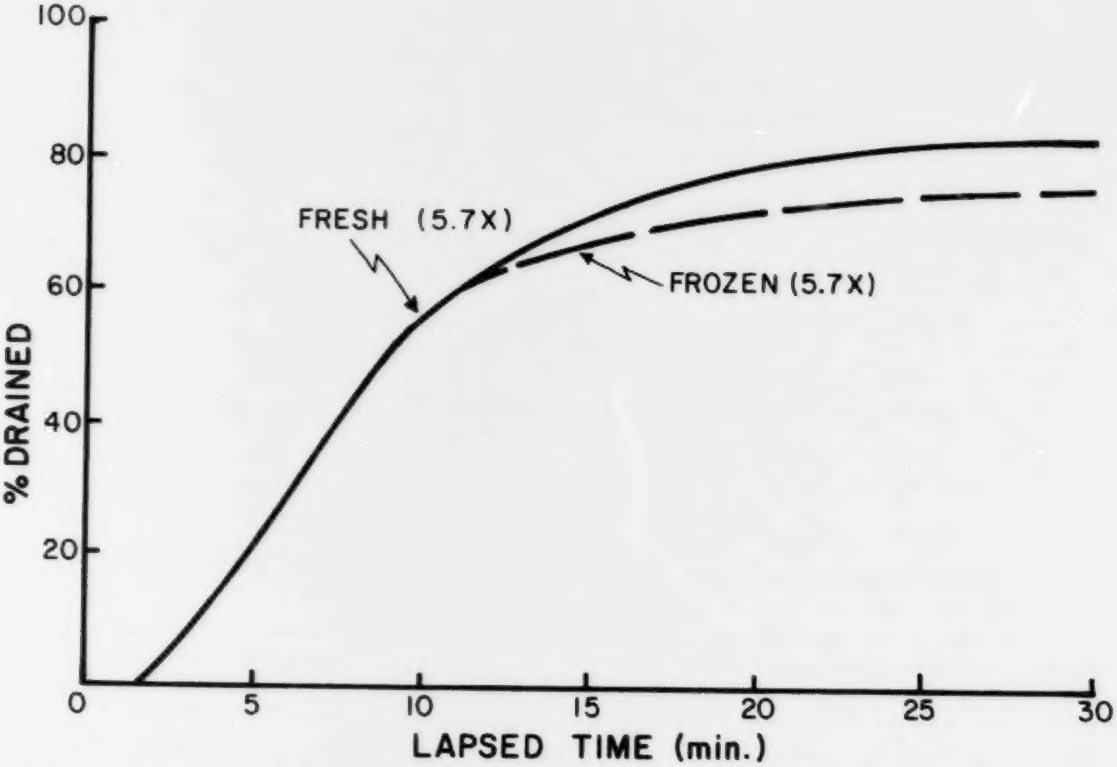

Figure 12. Comparison of rate of foam drainage for 0.65% solutions using fresh concentrate and concentrate which was frozen.

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USE OF ADVANCED CONCEPTS IN DISPATCHING FIRE CONTROL RESOURCES

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ABSTRACT

This paper reports on the development of the Intelligent Fire Management Information System (IFMIS), a computer program for dispatching fire suppression resources to wildfires. The program uses a number of advanced concepts to provide information to fire managers for both strategic and tactical purposes. Specifically, IFMIS integrates data bases, mathematical modeling, computer graphics, geographic information displays, and expert systems. The addition of expert knowledge bases and agency policies provides the fire manager with a greater decision support capability than that provided by traditional data processing approaches. The use of new computer programming languages, in conjunction with high-speed personal computers now makes this technology cost-effective enough to deliver to both forest and district level dispatchers.

INTRODUCTION

The dispatch of fire control resources to wildland fires is a complex process. The consequences of making the correct decision involves increasingly costly suppression resources and potential losses to valuable property and natural resources. The development of initial-attack decision support systems that employ state-of-the-art computer technologies is seen as essential to meet today's forest protection objectives. Computers have the potential to provide rapid and consistent decision support during periods of high fire loads. This paper reports on the development of a micro computer-based program for forest fire preparedness planning and initial attack dispatching. The Intelligent Fire Management Information System (IFMIS) integrates a number of advanced technologies including mathematical modeling, data base management, geographic information display, and expert systems. The goal of IFMIS is to provide a computer-based decision support system that can be used by forest fire managers for planning daily fire management activities, for real-time dispatching of fire control resources to new fires, and for training or simulation exercises.

BACKGROUND

Integrated decision support systems are not new to the Canadian forest fire management scene; the Fire Management System (FMS) developed by Kourtz (1984) at the Petawawa National Forestry Institute has been successfully implemented, either in whole or in part, in three provinces. Despite the varying success of this and other pioneering systems, the adoption of fire management information systems has generally been slow in Canada for a number of reasons. These include the high capital costs associated with the hardware platforms required for fire management systems, new continuing costs in the form of salaries for computer systems staff, the requirement to modify agency structure to meet software requirements, and the high cost associated with adapting computer software to a new location. This last point is especially true for expert systems, which tend not to be very portable from region to region.

The recent advent of powerful personal computers with their increased on-line memory and computational speed makes it possible to more-economically implement "desktop" fire management systems. So powerful are the new personal computers that they routinely outperform the pioneering systems in terms of computational speed and graphics capability. The personal computer has dramatically cut the costs for fire management systems, both in terms of capital and operating costs. There is also less need for specialized computer support staff. Advances in fire management systems have also be made possible by the availability of new programming languages, such as PROLOG and C, and by new expert system shells and data base managers.

CONCEPTUAL DESIGN

The Intelligent Fire Management Information System is a hybrid software system that integrates four advanced technologies: data base management, mathematical modeling, geographic information display, and expert systems.

Data Base Management

The development of decision support system for initial-attack dispatching demands large fire environment and fire management data bases. Consequently, data base management constitutes a considerable component of the IFMIS software. The data base management system (DBMS) is capable of handling large data volumes of varying formats. These data provide the essential inputs for the mathematical models, expert systems, and geographic display system. An example of the type and size of data bases used by IFMIS for the Alberta Forest Service's Provincial Forest Fire Centre installation in Edmonton are listed in Table 1.

Mathematical Modeling

IFMIS embodies full implementations of the two major subsystems of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks et al. 1989), the Canadian Forest Fire Weather Index System, and the Canadian Forest Fire Behavior Prediction System. In addition, IFMIS incorporates equations to calculate course distance, bearing, and estimated time of arrival (ETA) of fire control resources to reported wildfires. These and other mathematical process models are used in a library of custom functions to conduct preparedness planning exercises and real-time or simulated dispatch recommendations.

Geographic Information Display

The ability to incorporate the display of geographic information in a computer-based preparedness and dispatching system can greatly enhance its functionality. Data inputs and outputs from the CFFDRS can be viewed spatially. A module capable of geographic information display was implemented that permits the display of user-defined maps of variable scales. The map themes that can be displayed are user-defined and represent single or multiple variables from the data-base management system.

Expert Systems

Computer programs that undertake the solution of difficult tasks by using knowledge and mimicking the solution methods of human experts are called expert systems. The knowledge embodied in an expert system may be that of one or more human experts within a given field. The experience and knowledge of a forest fire dispatcher is one example of a knowledge domain that is narrow enough to encode in an expert system. Expert systems can also be used to encode scientific information, agency policies, and other information that may be too imprecise to define in terms of mathematical models.

Knowledge can be represented or encoded in expert systems using a number of different approaches. The most common of these is through the use of IF-THEN rules. A fifth-generation language called PROLOG is commonly used to build expert systems (Sterling and Shapiro 1986). To encode the dispatch rules, IFMIS uses what is called a PROLOG-based expert system shell. Kourtz (1987) has used pure PROLOG to build an expert system for initial-attack dispatch for the Societe de Conservation de l'Outaouis, which is responsible for forest fire control in southwestern Quebec. Although pure PROLOG can be used to write expert systems, the use of an expert system shell specific to the initial-attack dispatch problem was considered to provide greater ease of development and long-term maintenance. This approach has been described by Lee and Pickford (1987) for a demonstration expert system for use in dispatching suppression resources to wildfires on the Okanogan National Forest of the State of Washington.

One of the main advantages of using an expert system shell is that the primary concepts of the initial-attack expert system can be formulated using a taxonomic approach. This taxonomy or structure identifies all the elements considered to be essential in the dispatch decision. Once the taxonomy has been established it can be compiled into the main body of the PROLOG code. Attached to this is a rule compiler that takes near-English syntax IF-THEN rules and translates the knowledge base into PROLOG code. What this means is that the knowledge base of the initial-attack expert system can be readily maintained by non-PROLOG programmers with very little training. By coding the rules in near-English syntax, annual updating will be a relatively easy task. This ability to easily change the knowledge base due to changes in agency policy, the addition of new knowledge, or because of

Table 1. List of the primary data bases required for the Alberta Forest Service's Provincial Fire Centre IFMIS installation in Edmonton

Data base		Number of records
Name	Description	
CELL	Forest inventory and fuel type cells (64.8 ha)	512 000
GCELL	Generalized forest inventory and fuels cells (14.5 km^2)	41 400
WXSTN	Weather stations inventory	150
FWI	Fire weather	30 000
FFWI	Forecasted fire weather	30 000
FACILITY	Facility inventory	15 000
IABASE	Initial attack base inventory	200
TANKBASE	Air tanker base and airport inventory	200
SKIMMER	Skimmer lake inventory	1 200
ACSPECS	Aircraft specifications inventory	250
CREWS	Fire crew inventory	350
TANKERS	Air tanker inventory	15

regional differences makes the expert system shell approach appropriate.

SYSTEM DESCRIPTION

The IFMIS program consists of nine modules. The module acronyms and names are listed below in the order they appear on the main system menu:

INFO	System information
DEPLOY	Resource deployment
DETECT	Fire detection assessment
FWI	Canadian Forest Fire Weather Index System
FBP	Canadian Forest Fire Behavior Prediction System
MAPS	Geographic information display
DBMS	Data-base management system
GEO	Geographic coordinate conversion and measurement
REPORTS	Report writer

A brief description follows of how each module functions.

System Information

The INFO module provides general system utilities and operating system services. The module provides a description of the functioning of the context-sensitive help facility. A setup procedure is also provided for system customization.

Resource Deployment

The DEPLOY module of IFMIS consists of two major components: a resource allocation planning tool and resource location tracking system. This module uses mathematical programming and GIS computer graphics and expert systems technology to aid the fire manager in this very important day-to-day function.

The resource allocation planning tool combines agency policy rules, the CFFDRS subsystems, and fuel-type data to assist the dispatcher determining the appropriate resource levels. These levels are determined by using a spatial analysis approach.

The resource location tracking system automates the dispatch wall map found in most fire dispatch rooms. It archives, reports, and displays the location and status of fire crews, aircraft, air tankers, ground-based vehicles, equipment caches, and other resources as defined by the user.

Fire Detection Assessment

The DETECT module is composed of two submodules, 1) the Detection Assessment Report and 2) the Appropriate Suppression Response Expert System

(ASRES). Both submodules of DETECT can be used either in real-time or in simulation modes. When a fire is reported, the dispatcher enters fire report information, including the fire location. After the fire report information has been entered a number of calls are made to access the data base and to spawn mathematical computations.

Selecting the Detection Assessment Report option produces the report shown in Figure 1. This report summarizes the interpolated weather and FWI system components at the geographic location of the fire. Using fuel type information from the data base, it computes the forecasted fire behavior up until midnight. The fire behavior information provided includes an hourly summary of the predicted fire area, perimeter, and forward spread distance. It also identifies the presence or absence of crowning activity. The report also provides an ordered list of available initial-attack crews and air tankers. This list includes the distance, bearing, and estimated travel time to the fire for each resource.

The Appropriate Suppression Response Expert System embodies dispatcher expertise, agency policies, and scientific information using IF-THEN rules. These rules are coded in near-English syntax to make annual updating a relatively easy task. The dispatch knowledge base is also interpreted rather than being compiled, which reduces maintenance (programming) costs.

Central to the expert system is the determination of an appropriate initial response. Within the Alberta Forest Service, it is the goal of the dispatcher to ensure that the required fire control resources arrive at the new start within an appropriate time. The expert system relies heavily on the fire weather data, forest inventory data, and mathematical modeling to provide the user with an appropriate initial attack recommendation. Specifically, it uses the outputs described in the Detection Assessment Report. This factual information is imported to the expert system through the "fact pump." An example of the information provided by the expert system is shown in Figure 2. When the necessary data cannot be found in the data base, the expert system either asks the user for the missing information or infers from defaults encoded in the system. The user has the ability to ask the system why it needs the information being requested. The user can also ask the system to provide an explanation of how it determined the preferred force level.

Canadian Forest Fire Weather Index System

The FWI module is a complete implementation of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987). The module permits the input of morning, noon, and/or late afternoon fire weather observations and can be used to compute both actual and forecasted FWI System components. These outputs can be displayed using screen or printed graphics and in tabular reports. The graphic displays include maps, seasonal display charts, and bar charts. Figure 3 is an example of a Drought Code Season Display Chart for Berland Tower in the Whitecourt Forest. The FWI system components can also be displayed in map form (Fig. 4).

Canadian Forest Fire Behavior Prediction System

The FBP module implements the most-recent versions and modifications of the Canadian Forest Fire Behavior Prediction (FBP) System (Alexander 1985; Lawson et al. 1985; Alexander and De Groot 1988). The module provides for two methods of operation: manual and data base. The manual method functions as a calculator, querying the user for the standard FBP System inputs: FBP System fuel type, fine fuel moisture component of the FWI System, wind speed, slope, etc. The user can then elect to perform FBP System simulations that are either time, area, or distance dependent. Output can be directed to a printer as well as to the screen.

The data-base method performs FBP System projections using information from the data base. Required inputs are the date, time, and geographic location of the fire. From these inputs IFMIS will then perform FWI System and forest cover type data-base look-ups to interpret the weather, fuel, and terrain inputs. IFMIS interprets the FBP System fuel type from the cover type information. Weighted means are used when the stand contains multiple fuel types. FBP System projections can also be displayed in map form (Fig. 5) Fire intensity charts can also be displayed using the FBP module (Fig. 6).

Detection Assessment Report

Location: SW - 1 - 58 - 18 - 5 Date: JUNE 5, 1988 Ignition Time: 1615 MDT

Fire Weather/Danger Conditions:

Temp	RH	Wind	Rain	FFMC	DMC	DC	ISI	BUI	FWI	DSR
24.3	26	14.0	0.0	92.5	31.3	87	12.4	33.0	21.0	5.98

FBP System Fuel Types:

Species	FBP Fuel	% Cover
SB	C-2	65 %
SW	C-2	35 %

FBP System projections:

Elapsed (hh:mm)	Time LDT	FFMC	ISI	ROS (m/min)	Crowning potential	Dist. (km)	Area (ha)	Perim (km)
0:00	1615	92.2	11.8	13.3	No	0.0	0.0	0.0
0:15	1630	92.4	12.2	13.9	No	0.2	3.6	0.7
0:30	1645	92.6	12.5	14.5	Yes	0.4	15.1	1.4
0:45	1700	92.5	12.4	14.2	Yes	0.6	34.1	2.1
1:00	1715	92.3	12.0	13.6	No	0.8	59.3	2.8
2:00	1815	91.8	11.2	12.2	No	1.6	207.1	5.2
3:00	1915	91.1	10.1	10.5	No	2.2	404.7	7.3
4:00	2015	90.1	8.8	8.3	No	2.7	609.0	8.9
5:00	2115	89.5	8.1	7.3	No	3.1	820.6	10.3
6:00	2215	89.5	8.1	7.3	No	3.6	1063.7	11.8
7:00	2315	89.5	8.1	7.3	No	4.0	1338.2	13.2

L/B ratio: 1.35

Available crews:

ID	Base name	Resource type	Name	Status	Dist. (km)	Bear-ing	ETA (hh:mm)
W14	Grizzly	HA CREW	H-1	STANDBY	55.3	124	0:26
W32	Virginia Hills	IA CREW	I-3	STANDBY	57.4	212	0:29
W11	Tony	IA CREW	I-1	STANDBY	74.8	130	0:37
W42	Imperial	IA CREW	I-4	STANDBY	86.9	229	0:43
W21	Rat Creek	IA CREW	I-2	STANDBY	99.2	323	0:44

Available air tankers:

ID	Base name	Aircraft type	Group	Status	Dist. (km)	Bear-ing	ETA (hh:mm)
YQU	Grande Prairie	DC-6B	1	STANDBY	201.7	131	0:45
Loon	Loon River	DC-6B	3	STANDBY	362.9	195	1:21
YRM	Rocky Mountain House	SUPCANS	2	STANDBY	203.6	328	1:27

Figure 1. Detection assessment report for a simulated fire occurring at 1615 Mountain Daylight Time (MDT) on May 4, 1988, in the SW quarter of Section 1, Township 58, Range 18, west of the 5th meridian in the Whitecourt Forest of central Alberta.

Appropriate suppression response expert system summary

Initial attack strategy: Direct and indirect attack

Fire intensity rank: 3

Low to vigorous fire behavior.
Hand prepared fire line likely to be challenged.
Heavy equipment may be required.

Special considerations:

Gas plant located at SE-13-19-58 W of 5

Recommended appropriate suppression response:

Helitack crew 1 from W14 Grizzly

Air tanker group 1 from Grande Prairie

Figure 2. Appropriate suppression response expert system summary for a hypothetical fire occurring on May 4, 1988, in the SW quarter of Section 1, Township 58, Range 18, west of the 5th meridian in the Whitecourt Forest of central Alberta.

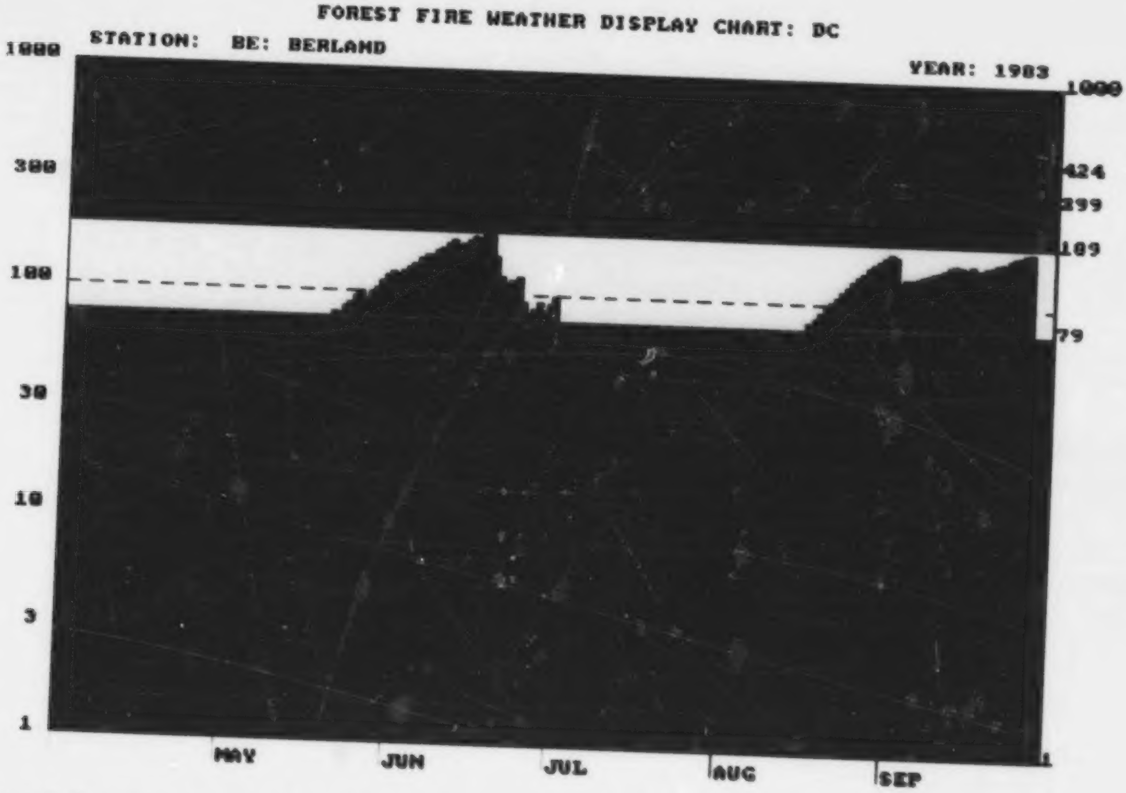

Figure 3. Seasonal display chart of 1983 Drought Code values for Berland Tower, Whitecourt Forest in central Alberta.

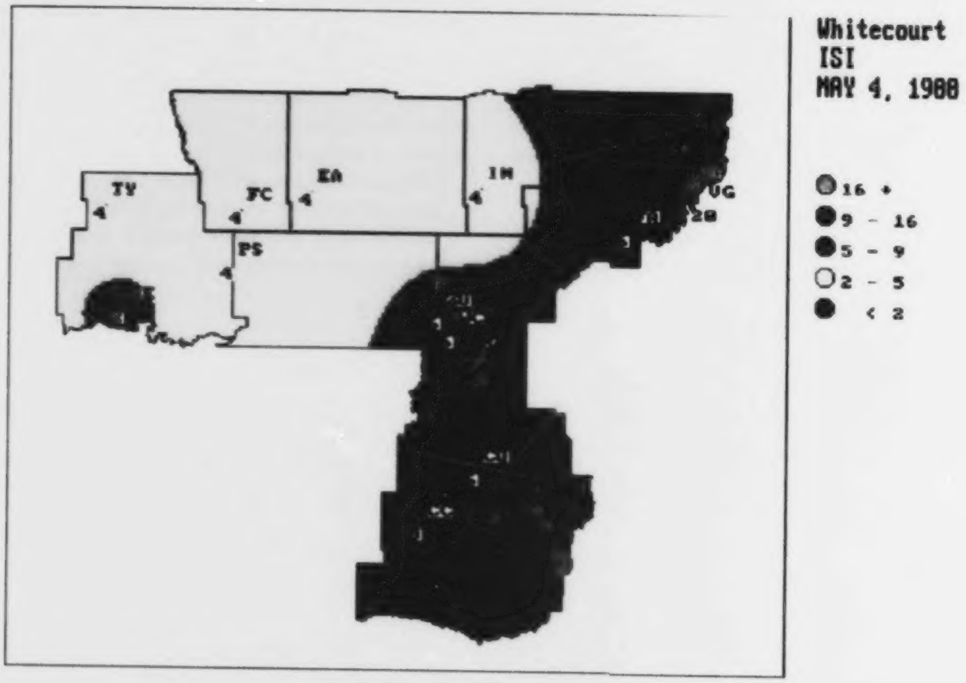
Whitecourt
ISI
MAY 4, 1988
● 16 +
● 9 - 16
● 5 - 9
○ 2 - 5
● < 2
TV
FC
EA
IM
PS
VG
4
4
4
4
4
20

Figure 4. Initial Spread Index (ISI) map for the Whitecourt Forest of central Alberta on May 4, 1988.

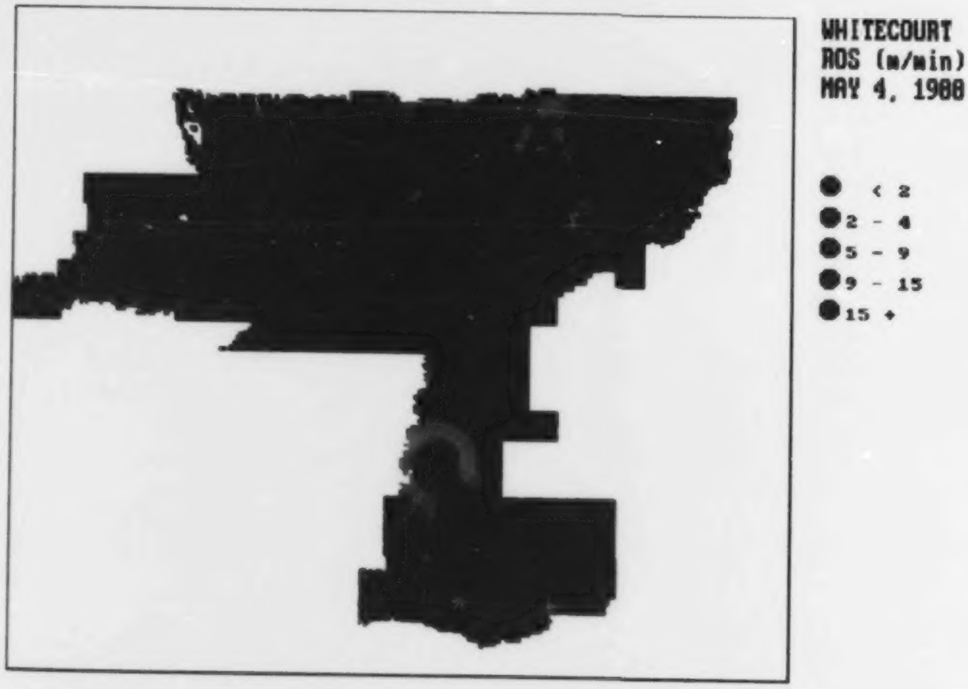
WHITECOURT
ROS (m/min)
MAY 4, 1988
● < 2
● 2 - 4
● 5 - 9
● 9 - 15
● 15 +

Figure 5. Predicted headfire rate of spread map for the Whitecourt Forest of central Alberta on May 4, 1988.

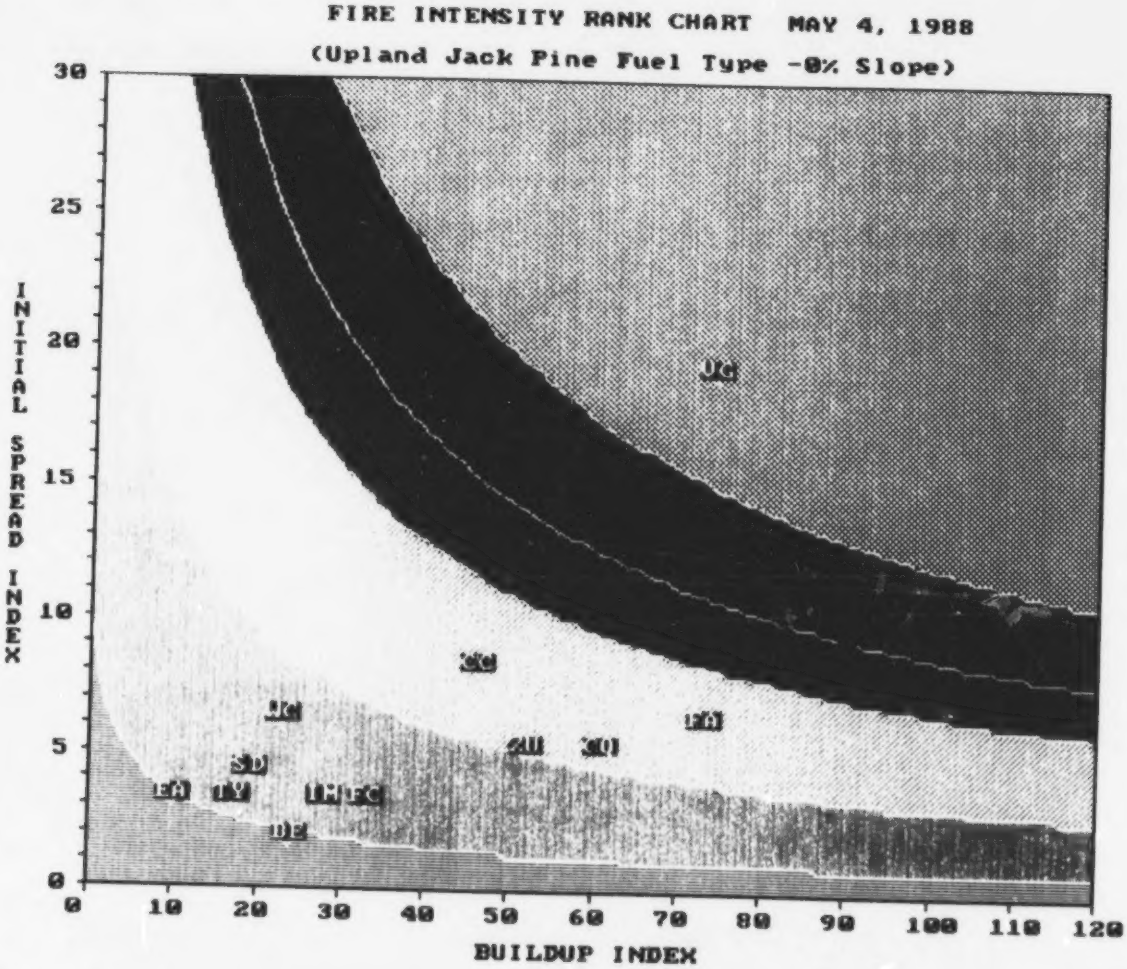

Figure 6. Fire intensity rank chart display for all fire weather stations in the Whitecourt Forest of central Alberta on May 4, 1988.

Geographic Information Display

The MAPS module implements a geographic information display system that permits the display of provincial or territory, forest or region, park, and cell (e.g., township, UTM, GEOLOC) scale maps. The map themes that can be displayed are user defined and represent single or multiple variables from the database management system. Some themes may include:

- Forest inventory
- Districts
- Protection priorities
- Resource values
- FWI System components
- FBP System components
- Suppression resources
- Road networks

An example map of FBP System fuel types for the Whitecourt Forest is presented in Figure 7.

Data Base Management System

The DBMS module of IFMIS spawns the data-base manager, which is used for general data base maintenance of system files.

Geographic Coordinate Conversion and Measurement

The GEO module of IFMIS provides the user with a number of geographic utilities for converting between various coordinate systems and for calculating the distance, bearing, and time to travel between two geographic locations.

Report Writer

A REPORTS module provides a facility for reporting on selected IFMIS data bases using predefined

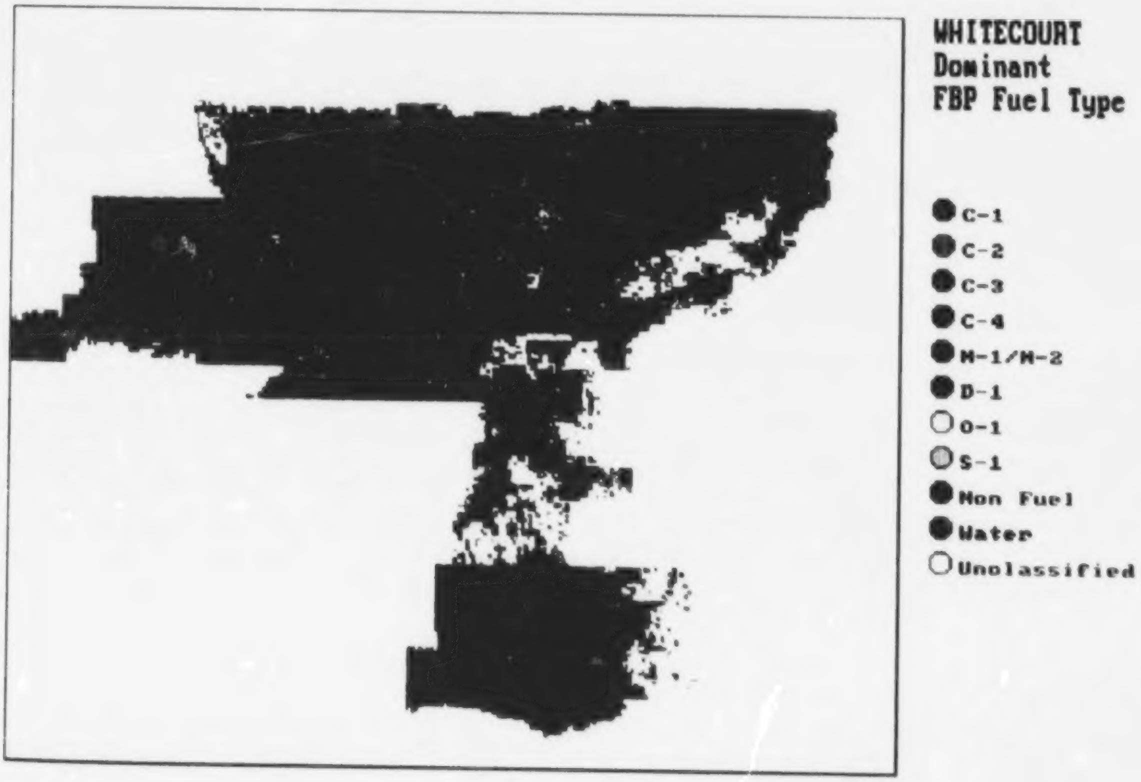

Figure 7. FBP System fuel types for the Whitecourt Forest in central Alberta.

queries. These queries can be directed to the screen, a printer, or a file.

IFMIS IMPLEMENTATION

Operational prototypes of IFMIS will be installed at three locations in Alberta and one location in Saskatchewan for the 1989 fire season (Fig. 8). By the 1990 fire season, IFMIS will be operational in all provincial and most regional forest fire centers of Alberta, Saskatchewan, and Manitoba.

IMPLICATIONS FOR FOREST FIRE MANAGEMENT

The integration of the four technologies described above will, when completely operational, provide the forest-fire dispatcher with a wide range of usable information in a form that is easy to use and understand. The application of forecasted and actual weather using a spatial interpolation approach will provide better estimates of fire weather and fire behavior potential. The integration of geographical information displays of forest cover type, FBP System fuel type, and terrain data will provide more accurate and reliable fire intelligence data on which to base potentially costly decisions. The presuppression planning capabilities of IFMIS will result in better allocation of initial-attack crews and air tankers. The operational use of the computer-based fire detection assessment (smoke) reports that analyze the interpolated weather conditions, predicted fire behavior, and nearest available resources to assist the dispatcher in ensuring that the most appropriate resources are allocated to fire will no doubt become common place and routine in the near future.

CONCLUSIONS

The forest-fire dispatcher will be required to incorporate increasingly more information into daily decision-making to reduce suppression costs and damages to values-at-risk. Without the application of advanced computer technology such as that described in this paper, it will not be possible to incorporate this increase in information into the decision-making process. Decision support systems designed for initial-attack dispatching, such as IFMIS, will be able to compensate for these increased demands by successfully implementing expert systems to act as assistants to the forest-fire dispatcher. The operational use of expert systems will not occur overnight but will take many years of research, development, and testing. The demystification of computers and new technologies such as artificial intelligence, expert systems, and geographic information systems will no doubt yield even greater benefits for fire management practitioners in the near future.

ACKNOWLEDGMENTS

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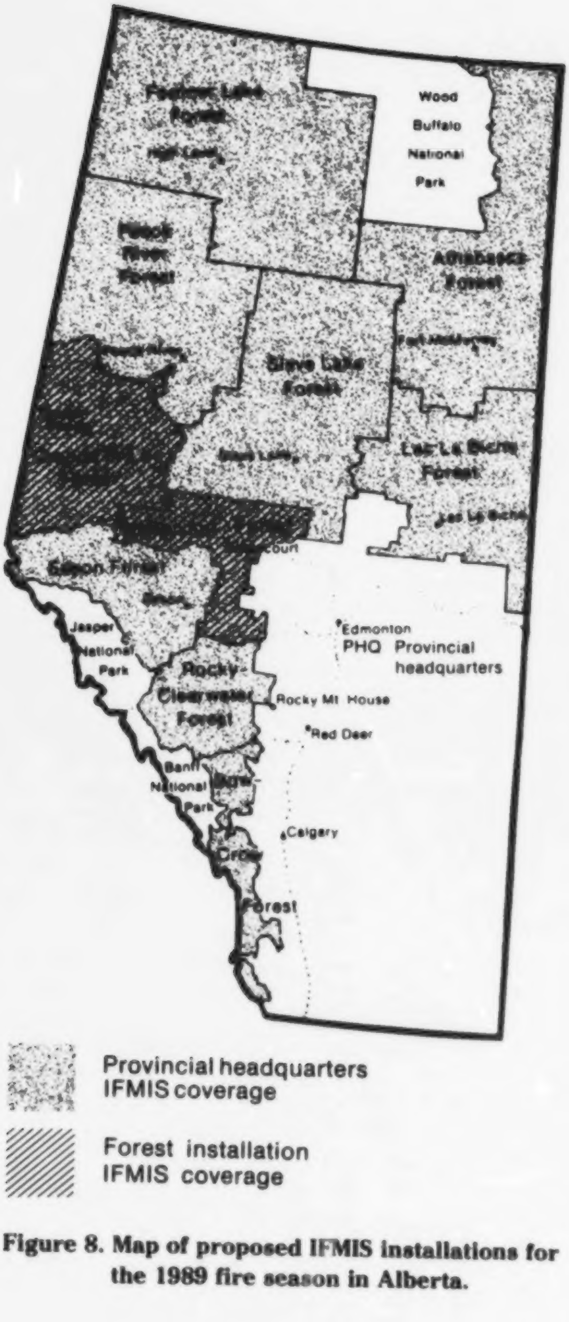

Footner Lake Forest
High Level
Wood
Buffalo
National
Park
Peace
River
Forest
Athabasca
Forest
Fort McMurray
Slave Lake
Forest
Slave Lake
Lac La Biche
Forest
Lac La Biche
court
Edson Forest
Edson
Jasper
National
Park
Edmonton
PHQ Provincial
headquarters
Rocky-
Clearwater
Forest
Rocky Mt House
Red Deer
Banff
National
Park
Bow-
Calgary
Crow
Forest
Provincial headquarters
IFMIS coverage
Forest installation
IFMIS coverage

Figure 8. Map of proposed IFMIS installations for the 1989 fire season in Alberta.

PREDICTING PRESCRIBED FIRE EFFECTS ON TREES IN THE INTERIOR WEST

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ABSTRACT

Consistent success in prescribed underburning requires managers to specify acceptable levels of fire injury and to describe the fuels, weather, and fire behavior necessary to accomplish the objectives. Information is assembled to assist managers in this process. Relationships between fire behavior, tree morphology, and fire injury are discussed. Implications of fire injury on the survival and growth of trees are presented. Guidelines are presented for establishing acceptable levels of crown, bole, and root injury and for limiting injury to acceptable levels.

INTRODUCTION

Successful prescribed burning beneath standing trees is both an art and a science. It is an art because there are always local variations in fuels, vegetation, weather, and fire behavior that defy precise quantification. These are understood best by an experienced manager who is knowledgeable of local conditions. Science provides the foundation for sound fire management, and its fundamental relationships apply broadly across environments.

This paper presents concepts of fire injury to trees and techniques for controlling the injuries sustained during prescribed burning. Objectives are to identify prescription factors necessary for burning coniferous stands, to provide acceptable limits of fire injury, and to describe techniques for predicting and controlling fire injury resulting from prescribed burning.

RESOURCE GOALS VS. PRESCRIBED FIRE OBJECTIVES

Managers increase the likelihood of success by the professional execution of a carefully planned burn. Fundamental to careful planning is a clear statement of attainable objectives (Norum 1977; Fischer 1978; Martin and Dell 1978; Brown 1985; Kilgore and Curtis 1987). Because long-term resource management goals such as growth or regeneration are influenced by many factors other than fire (Fig. 1), such goals are not suitable prescribed fire objectives. Translating resource management goals into fire objectives requires integration of biological information with fire behavior factors. Fire objectives must be expressed in terms of the direct consequences of fire. In the case of prescribed underburning, managers need to specify short-term direct fire effects (e.g., the type and degree of fire injury) that are compatible with long-term resource goals. Prescriptions are then developed to limit injuries to acceptable levels.

Fuels (their amount, moisture, and distribution), weather (particularly temperature, humidity, and wind), and the ignition pattern form the operational elements of the burning prescription. These elements link the burning prescription with the fire objectives. Fuels, topography, and weather dictate how much fuel is available for combustion and thus the potential energy release in a prescribed burn. The ignition pattern largely dictates how the available energy will be released and, therefore, the observable fire behavior. The rate and duration of energy release dictates how much fire injury occurs in a given stand.

Figure 1 illustrates the process of linking resource management goals with fire objectives. Establishing links between fire behavior and survival and growth requires an understanding of how fire-caused injuries result from interactions between the fire behavior and tree morphology. A better understanding of how physiological processes, and hence survival and growth, are affected by fire injury also helps establish acceptable limits of injury.

Little research has been conducted on the growth of fire-injured trees in the Interior West (Morris and Mowat 1958; Lynch 1959; Landsberg et al. 1985; Reinhardt and Ryan 1988a). These studies do not show

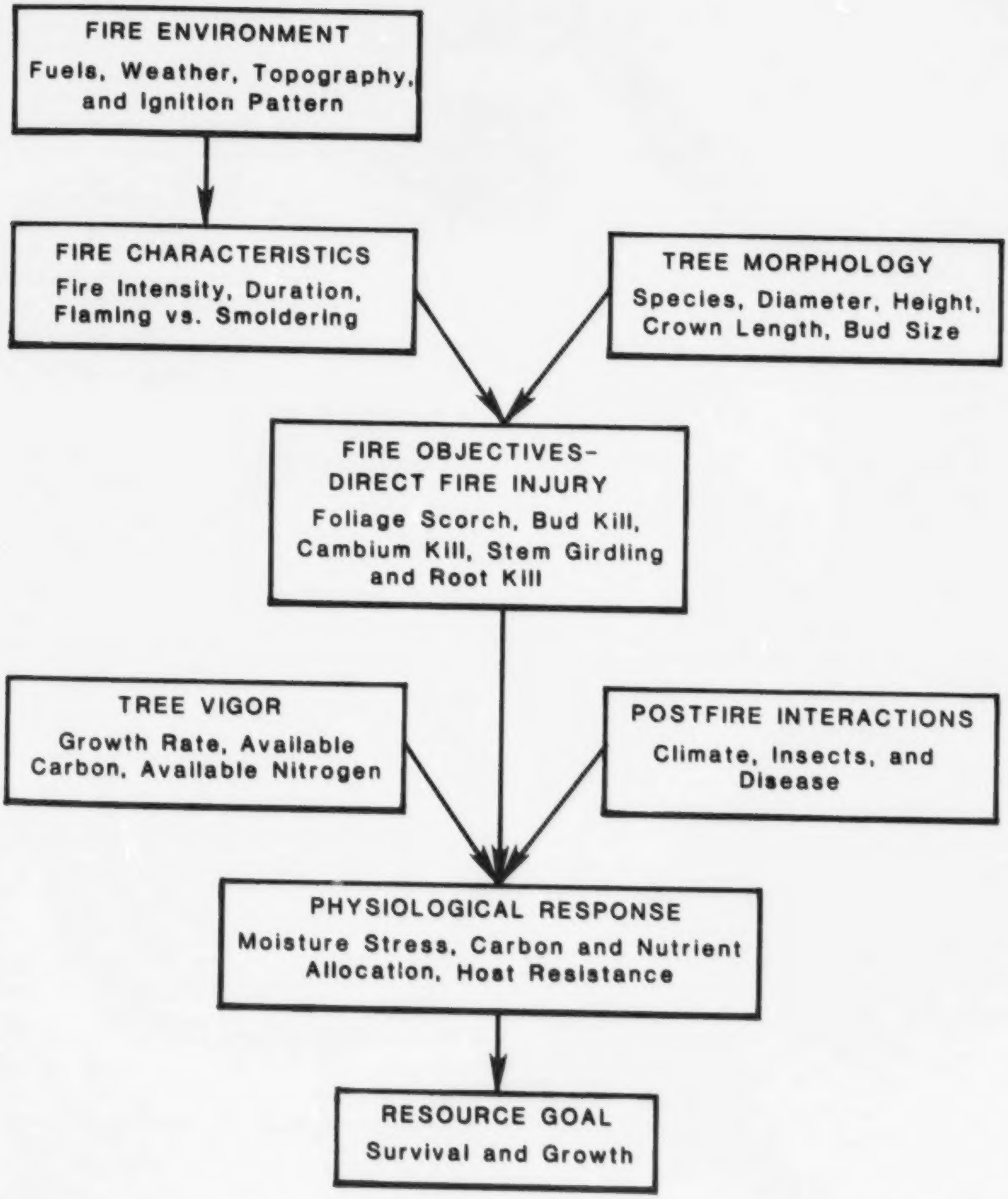
FIRE ENVIRONMENT
Fuels, Weather, Topography, and Ignition Pattern
FIRE CHARACTERISTICS
Fire Intensity, Duration, Flaming vs. Smoldering
TREE MORPHOLOGY
Species, Diameter, Height, Crown Length, Bud Size
FIRE OBJECTIVES-DIRECT FIRE INJURY
Foliage Scorch, Bud Kill, Cambium Kill, Stem Girdling and Root Kill
TREE VIGOR
Growth Rate, Available Carbon, Available Nitrogen
POSTFIRE INTERACTIONS
Climate, Insects, and Disease
PHYSIOLOGICAL RESPONSE
Moisture Stress, Carbon and Nutrient Allocation, Host Resistance
RESOURCE GOAL
Survival and Growth

Figure 1. Factors to consider when translating a resource management goal into a prescribed underburning objective.

consistent results in part because of variations in species, site, stand vigor, and the type and degree of fire injury. Physiological responses affecting the survival and growth of fire-injured trees have not been investigated. Numerous studies have, however, documented postfire survival of Interior West trees (Lynch 1959; Dieterich 1979; Bevins 1980; Mitchell and Martin 1980; Ryan 1982; Peterson and Arbaugh 1985; Wyant et al. 1986; Harrington 1987; Ryan et al. 1988; Ryan and Reinhardt 1988).

In the following two sections a survey of literature will be used to develop an understanding of the fire injury process, to speculate on the physiological consequences of fire injury, to establish acceptable levels of fire injury, and to present preliminary guidelines for developing underburning prescriptions.

FIRE EFFECTS ON TREES

The extent of fire injury depends on how much heat a fire produces, mechanisms of heat transfer, and a tree's resistance to injury. It is common knowledge that resistance to fire injury varies both with species and tree size. Resistance depends primarily on the morphological characteristics of bud size, rooting pattern, and bark thickness. Knowledge of these differences is important for understanding and controlling the effects of fire on trees. When evaluating potential fire effects on trees, three morphological components should be considered: crown, roots, and stem. The fire characteristics and dominant mode of heat transfer associated with injury to each component are relatively independent; thus, a separate prescription element should be developed to control injury to each one.

Tissues are injured when their temperature rises beyond certain tolerance limits that depend on the magnitude of the temperature increase and the duration of exposure. For example, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) cambium can survive approximately 50°C for 1 hour, 60°C for 1 minute, and 70°C for 1 second (Martin 1963a). There are minor seasonal and tissue differences in the time versus temperature relationship (Hare 1961; Wright and Bailey 1982); however, thermal gradients in fires are generally very steep, i.e., temperatures drop rapidly over short distances. As a consequence, if a tissue reaches 50°C it likely will also reach 60°C and 70°C. In fire applications there is therefore little practical difference in the maximum temperature that various tissues can survive, and 60°C is often assumed to be the average lethal temperature (Van Wagner 1973; Peterson and Ryan 1986). Because average combustion zone temperatures may be 10 times greater than lethal temperatures, tissues must be either distant from the combustion zone or well insulated to survive.

Injury also depends on the tissue's initial temperature (Byram 1948; Van Wagner 1973; Peterson and Ryan 1986), the amount of heat released by the fire, and the mechanism of heat transfer (e.g., convection, conduction, and radiation). Initially, conifer needles and roots are in equilibrium with the ambient air and soil temperatures, respectively. In full sunlight, stem phloem and cambium may be up to 10°C higher than the air temperature (Nicolai 1986). The heat released varies with the fire's intensity and duration. The intensity associated with the initial active flaming phase is better understood and modeled (Rothermel 1983; Stocks et al. 1989) than is the duration of residual flaming and glowing combustion. As a result, the prediction of fire effects associated with the active flaming phase (e.g., crown scorch) is on firmer ground than is the prediction of effects that are more strongly dependent on the duration of heating such as stem and root injury.

Crown Injury

The crown consists of foliage, buds, and supporting branchwood. Because foliage is small and poorly insulated it is relatively easy to kill. Foliage death is not, however, as critical to tree survival as is death of buds and branch cambium (Ryan 1982; Peterson and Ryan 1986; Ryan and Reinhardt 1988). This is because foliage scorch represents a temporary reduction of leaf area whereas bud and twig kill represent permanent losses. Buds are more resistant to heat than foliage is, particularly if the buds are large (Byram 1948) and if bud scales have formed (Wagener 1961). The pattern of foliage distribution along twigs is also important for protecting buds. Long-needle conifers tend to shield buds from heating. Relative to foliage, branch cambium is well insulated and resistant to heat.

Because buds are more resistant than foliage to thermal injury, the height of bud kill may be somewhat less than the height of foliage kill. General rules from Peterson and Ryan (1986) may be used to make seasonal and species adjustments for differences between foliage scorch and crown kill; however, only species with large or shielded buds are likely to experience enough difference between foliage scorch and bud kill to be of practical importance in operational burning. Death of dormant buds of ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*P. contorta* Dougl.), western white pine (*P. monticola* Dougl.), and western larch (*Larix occidentalis* Nutt.) generally occurs at about a 20% lower height than foliage.

Tree vigor and crown ratio (crown length:tree height) also influences survival. Figure 2 illustrates how the pattern of mortality resulting from crown kill alone varies with tree vigor. It is based on a synthesis of several studies (Lynch 1959; Wagener 1961; Methven 1971; Ryan 1982; Spicer 1982; Harrington 1987; Swezy 1988) rather than an empirical data set. In general, immature, rapidly growing trees have a better chance of surviving a given proportion of crown injury than older, slow-growing trees. For example, young ponderosa pine can survive 100% foliage scorch if 20% of the buds survive (Lynch 1959), but 40% bud survival appears to be a minimum for older trees (Herman 1954).

Age-size differences in survival and growth may be explained, in part, by changes in a tree's carbon balance. The amount of photosynthesizing leaf area increases during early life but levels off as trees approach maturity. The amount of respiring biomass, however, continues to increase throughout a tree's life. Survival and growth are strongly dependent on the ratio of photosynthesis to respiration. As this ratio approaches unity, the carbon available for growth and chemical defense against insects and disease becomes limiting. Older trees use a greater proportion of available carbohydrates for maintenance respiration and have less to allocate to repair and defense (Waring and Schlesinger 1985; Chambers et al. 1986).

Carbon balances of fire-injured trees have not been quantified, but simulation of seasonal net photosynthesis with the DAYTRANS physiological process model (Running 1984) illustrates potential effects of crown kill in an immature western Montana lodgepole pine stand (Fig. 3). The model predicts that a 20% foliage reduction results in reduced transpiration and lower moisture stress. This leads to greater photosynthesis in residual foliage. As a result, seasonal net photosynthesis is only predicted to decline by 9%. A 60% reduction in foliage, however, results in a predicted 53% reduction in seasonal net photosynthesis.

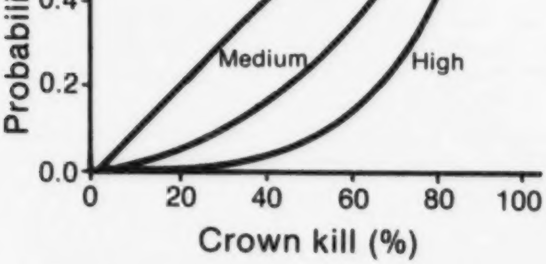

Figure 2. Stylized influence of tree vigor (low, medium, and high) on mortality resulting from crown kill based on a survey of fire-caused mortality studies.

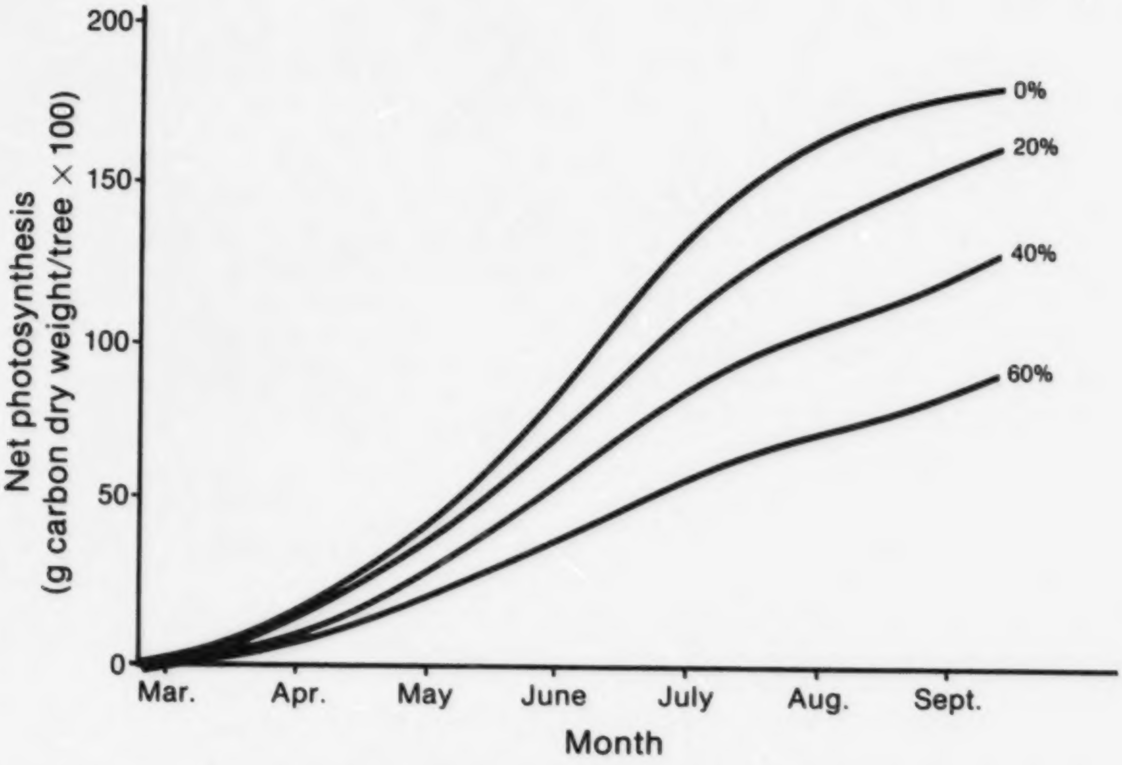

Figure 3. Simulated seasonal net photosynthesis resulting from percentage leaf area reduction due to foliage heating during fire.

Production of stem-wood and host resistance to insects and disease are lower on a tree's hierarchy of carbon allocation than production of crown and root tissues (Waring and Pitman 1985). Thus, at least temporary reductions in stem growth and production of defensive chemicals should be expected from heavy crown scorch. In the Interior West, species with small buds tend to have longer needle retention periods, and partial defoliation can be expected to have longer lasting effects on growth and insect and disease resistance.

Epicormic branching is an important mechanism of crown recovery for some genera in various parts of the world, but it is not known to be important in any species in the Interior West. Minor crown recovery occurs from epicormic branches in Douglas-fir in the first few feet below the foliage scorch height, but it appears to be of marginal utility to the total carbon balance of the tree. Crown recovery in severely scorched western larch appears to result from survival of buds within the spurlike lateral branches rather than from epicormic buds.

As a rough guide, burning prescriptions should aim for maintenance of a crown ratio of at least 0.4 for mature and overmature trees if good survival and growth are desired. A ratio of 0.3 may be satisfactory for vigorous young trees. If the prefire crown ratio is less than desirable, the prescription should limit the crown kill height to less than the crown base height.

Root Injury

For predicting the effects of fire on roots, the root system is broadly considered to include root crown, coarse roots, fine "feeder" roots, and the associated mycorrhizae. Root spatial distribution, root crown bark thickness, and thickness and dryness of the duff (fermentation and humus soil horizons) determine the extent of root injury. For example, the probability of cambium survival at the root crown declines in mature ponderosa pine as the depth of duff consumed adjacent to the cambium increases (Fig. 4). These mature pines are considered second only to western larch in fire resistance among conifers of the Interior West; however, when long fire-free intervals lead to deep accumulations of duff, even these trees may be injured by heat from a smoldering ground fire.

The effect of root crown injury on survival and growth has not been adequately quantified. Wagener (1961) suggests white pines survive basal girdling of up to 60% of the circumference, but other species have a low chance of survival if more than 25% is girdled. This contrasts with mechanical girdling studies that suggest that girdling must be nearly complete to kill a tree (Noel 1970). Preliminary results of work in progress indicate that, in the absence of significant crown injury, most trees survive up to 25% basal girdling, but few trees survive more than 75%. Between these ranges about one-half of the trees survive. The apparent higher death rate of trees girdled by fire may indicate that injury to physiologically active roots commonly occurs in conjunction with basal girdling.

Vertical root distribution is also important. Rainfall patterns, soil structure and nutrition, and successional status affect root distribution. Early successional or intolerant species tend to be more deeply rooted than later species (Gale and Grigal 1987). In the Interior West, western larch and ponderosa pine are generally deep rooted (Brown and Davis 1973). Douglas-fir may be deep-to-shallow rooted depending on whether it occurs as an early or late successional species. Lodgepole pine is moderately deep rooted except on pumice soils where its roots are shallow. Western white pine, white fir (*Abies concolor* [Gord. and Glend.] Lindl.), and grand fir (*A. grandis* [Dougl.] Lindl.) are moderately shallow rooted. Western red cedar (*Thuja plicata* Donn), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), Engelmann spruce (*Picea engelmannii* Parry), white spruce (*P. glauca* [Moench] Voss), and subalpine fir (*A. lasiocarpa* [Hook.] Nutt.) are shallow-rooted species (Minore 1979).

Regardless of the initial rooting pattern, most fine "feeder" roots and their mycorrhizae are found in the

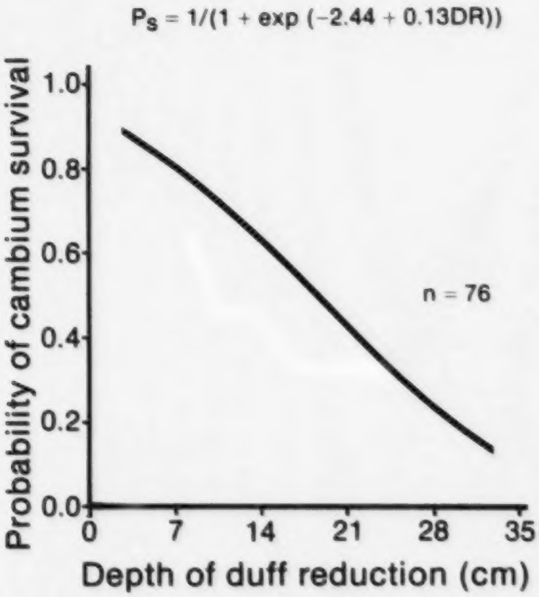

Figure 4. Probability of cambium survival in mature ponderosa pine versus depth of duff reduction.

duff and upper mineral soil. Heat penetration into these layers can injure these tissues. Root injury effects have not been quantified, but the DAYTRANS model (Running 1984) can be used to illustrate potential physiological responses to root loss in a lodgepole pine stand in western Montana. Decreasing root volume leads to an earlier onset and greater magnitude of moisture stress, frequent stomatal closure, and reduced photosynthesis. As seasonal net photosynthesis declines (Fig. 5), less carbon is available for growth and protection from insects and disease. Healthy trees growing under favorable environmental conditions should be able to replace fine feeder roots if crown injury is minimal; however, extensive injury to fine roots may lead to higher growth losses and mortality of less vigorous or stressed trees (Chambers et al. 1986).

Coarse roots provide structural support and carbohydrate storage. They are generally deep in most pioneer species and are not likely to be directly killed by fire unless considerable duff is consumed. This can occur when long fire-free intervals lead to duff accumulation in fire-prone stands. As duff accumulates, coarse roots are also found in organic soil horizons and become susceptible to injury during heavy duff consumption. It is therefore best to avoid extensive soil heating unless root injury is desired.

Fire injury to roots leads to fungal infection, chronic stress, and growth losses (Littke and Gara 1986). It is speculated that root injury is probably of greater significance in growth losses and mortality of thick-barked trees than is stem injury (Sofronov and Volokitina 1977; Ryan 1982; Swezy and Agee 1988; Harrington and Sackett 1989). Coarse roots are diseased in some older trees, and if fire injures fine surface roots, moisture stress, windthrow and mortality may result (Stewart and Hagle 1988). If root disease problems are suspected and the objective is to minimize mortality, duff consumption should be minimized. If the burn site is a shelterwood or seed-tree unit and the objective is to create a mineral soil seedbed, then it may be necessary to leave more trees

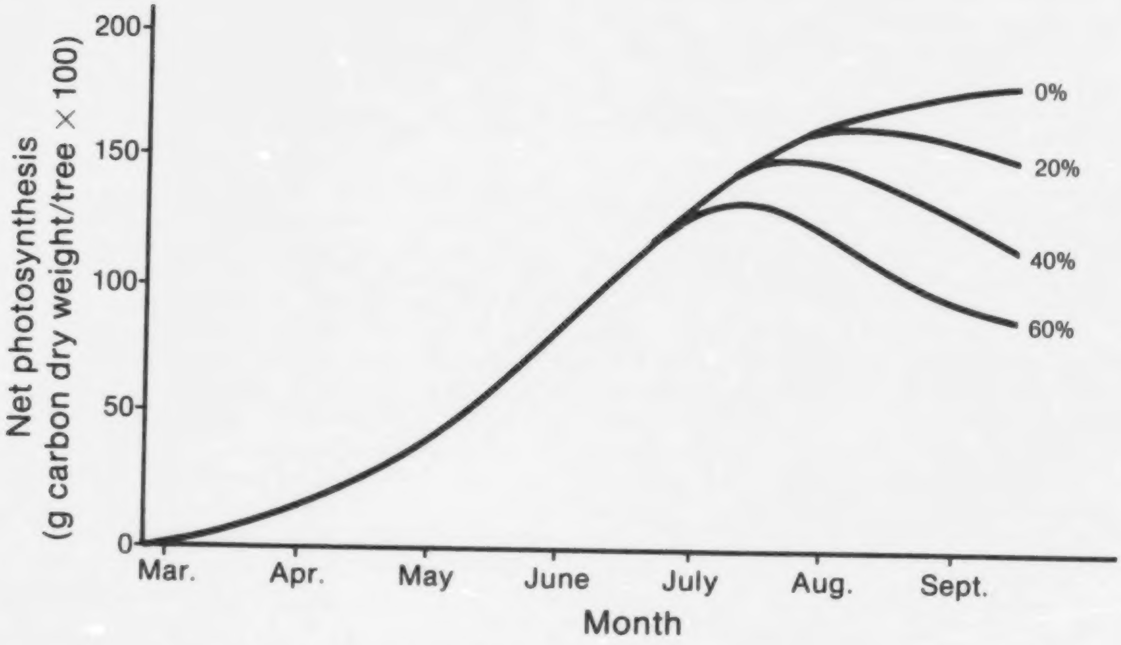

Figure 5. Simulated seasonal net photosynthesis resulting from percentage fine root reduction due to soil heating during fire.

to increase the likelihood that an adequate number survive.

Stem Injury

The stem (trunk or bole) includes phloem, cambium, xylem parenchyma, and their protective dead outer bark. Over a wide range of surface fire conditions the primary factors controlling the likelihood of stem injury are the fire's duration and the tree's bark thickness (Ryan 1982). A tree's resistance increases with the square of its bark thickness at approximately 3 min/cm (Martin 1963b; Ryan 1982; Peterson and Ryan 1986). Thus, doubling bark thickness from 1 to 2 cm increases the duration needed to injure the cambium from 3 to 12 minutes. Bark thickness generally increases linearly with diameter and varies with species (Ryan 1982; Ryan and Reinhardt 1988).

Little is known about the physiological effects of fire injury on stems. Stems transport water, nutrients, and hormones to the crown and carbohydrates to the roots. They also store water, nutrients, carbohydrates, resins, and terpenes. Injuries that seriously interrupt these processes can adversely affect survival and growth. Killing of large areas of cambium may disrupt carbohydrate flow to roots resulting in reduced production of fine roots and ultimately leading to moisture stress. Resinosis and subsequent deterioration of sapwood may increase resistance to xylem transport and reduce stem water storage capacity, which may lead to increased moisture stress. For example, Rundel (1973) found that the incidence of dead tops (an indicator of chronic moisture stress) increased as the size of old fire scars increased.

The effect of cambium injury on tree survival has not been adequately quantified. Wagener (1961) suggests that cambium injury to more than one-fourth of the circumference above stump height seriously reduces the chances for tree survival. Ryan et al. (1988) determined the probability of long-term fire-caused mortality of Douglas-fir. Half of the trees with dead cambium in one or two quadrants at breast height eventually died. Trees with dead cambium in more than two quadrants were poor candidates for survival. As a rule, cambium injury should not exceed one quadrant if high tree survival is desired.

Generally, cambium injury that occurs high on the stem is more critical to survival than similar injuries lower on the stem (Wagener 1961; Ryan 1982). Reasons for this are not clear. Damage high on the stem may be more disruptive of xylem and phloem transport. Alternatively, it may be that the conditions leading to cambium injury high on the bole are conducive to injury to the lower stem and roots, but these have gone undetected in previous studies. Data from nearly 1000 trees, including a range of diameters and five species, indicate that on average, cambium injury is 20% greater at stump height (0.3 m) than it is at breast height (1.4 m) (Ryan 1989). Regardless of the causal mechanism, care should be taken to minimize excessive heating high on the bole if high tree survival is desired.

Interactions Between Injuries

Species morphology and stand conditions often predispose trees to multiple injuries. For example, in the Interior West, species with shallow roots tend to have thin bark, which makes them susceptible to both root and stem injury. Multiple injuries also become more common as fuel consumption and fire intensity increase. Figure 6 illustrates the combined effect of crown and stem injury. It is based on a logistic regression model developed from data on Douglas-fir trees (n = 352) in western Montana. The trees were burned in 20 prescribed fires in natural fuels. Although burning was conducted to minimize crown injury, some trees were severely scorched. The interaction of crown injury and unconstrained stem injury caused many trees to die. Dashed lines in Figure 6 indicate the limits of the data, but, based on Figure 2, we would expect all lines to converge to one as crown kill approaches 100%. The model underpredicted stand mortality by 7%, which may reflect the occurrence of unquantified root injury. Additional study details are contained in Ryan et al. (1988).

Reinhardt and Ryan (1988b) developed a nomogram that provides estimates of the flame length needed to achieve a given probability of mortality in a wide variety of stands. The nomogram is based on resistance to mortality from the combined effects of crown and stem injury associated with common operational burning conditions in the region. Their results indicate that high mortality occurs in thin bark trees regardless of crown injury and in thick bark trees only at high crown kill. Mortality is also high in trees with moderately thick bark when crown kill is moderate. Their data did not include trees burned with thick, dry duff or light, fine surface fuels. As a result, the nomogram may underpredict mortality for thick-barked trees burned in long duration fires or overpredict mortality of thin-barked trees burned in short duration fires.

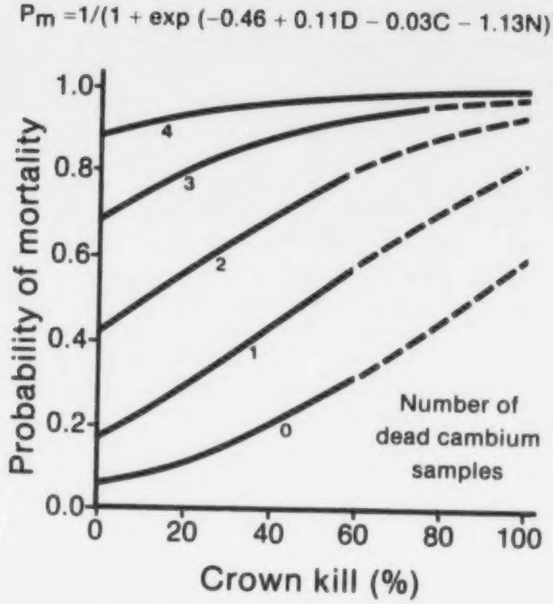

Figure 6. Probability of mortality of 25-cm diameter at breast height (D) Douglas-fir trees (n = 352) as a function of percentage of prefire crown killed and the number of quadrants (0 to 4) with dead cambium at 1.4 m height above ground (N). Dashed lines are beyond the limits of these data.

PRESCRIPTION DEVELOPMENT

When developing burning prescriptions it is necessary to establish levels of injury that are compatible with long-term management objectives. The preceding discussion should help managers set these limits. The following discussion, plus guidelines for predicting fire behavior (e.g., Rothermel 1983; Burgan and Rothermel 1984; Andrews 1986; Alexander and De Groot 1988; Andrews and Chase 1989) and prescribed burning (e.g., Martin and Dell 1978; Ryan 1982; Gruell et al. 1986; Kilgore and Curtis 1987; Reinhardt and Ryan 1988b) should help managers identify the fuel and weather conditions and ignition techniques suitable for underburning coniferous stands in the Interior West.

Predicting and Controlling Crown Injury

Crown injury is caused primarily by convected heat (hot gases rising above the fire). The visual fire characteristic most closely associated with crown injury is the flame length. Flame length equates to the fireline (or frontal fire) intensity (Byram 1959). Because fireline intensity cannot be observed, flame length is the preferred prescription parameter. Flame length depends primarily on the rate at which fine surface fuels are ignited and burned. Thus, prescription elements dictating the amount of burnable fine fuel and ignition pattern are critical to controlling crown injury. The most important fuels to consider when evaluating potential crown scorch are unit average 1-hour (.6 cm diameter) and 10-hour (0.6-2.5 cm diameter) time-lag fuel loadings and their moistures. These fuels are primarily consumed in the active flaming phase and are associated with the maximum fireline intensity. The best available technique for estimating crown kill is Van Wagner's (1973) scorch height model. It is based on the observation that the temperature attained at a height above a fire is a function of Byram's (1959) fireline intensity, ambient air temperature, and wind speed. Graphical solutions of the scorch height model are found in Albini (1976), Norum (1977), and Reinhardt and Ryan (1988b). Techniques are available for predicting fireline intensity and flame length in fire behavior systems from both Canada (e.g., Alexander and De Groot 1988) and the United States (e.g., Burgan and Rothermel 1984; Andrews 1986). These may be used to predict scorch height from fires in various fuel types and burning conditions. Combining the scorch model and fire behavior prediction gives managers a tool to develop prescriptions for achieving the desired fire behavior.

Predicting and Controlling Root Injury

Roots are injured by heat conducted downward from the fire. Wet duff protects roots from surface fire heat (Frandsen and Ryan 1986). Dry duff is a poor conductor but is a potential fuel. It may burn for several hours by smoldering combustion (Ryan 1982). The burnout of the duff is the primary source of heat injury to roots and causes root crown girdling. Thus, prescription elements dictating the desired amount of duff consumption are critical for controlling these injuries.

The depth and moisture contents of duff beneath the tree crown are the primary factors to consider when assessing potential root injury. This duff is usually deeper than the average duff on the unit because most of the needle litter and bark flakes fall near the tree. It is also often dryer because of canopy interception.

Methods are available for predicting duff reduction in various stands in the Intermountain West (Shearer 1975; Norum 1977; McRae 1979, 1980; Sandberg 1980; Brown et al. 1985; Reinhardt et al. 1989). In general, nearly complete duff reduction occurs when duff moisture is below 35%. Consumption of thin duff steadily declines above this point; however, deep duff may burn at moisture contents as high as 90% (Harrington and Sackett 1989). At duff moisture contents above 120%, duff consumption is minimal. Duff moisture content has been related to fire danger rating systems from both Canada (Van Wagner 1987) and the United States (e.g., Sandberg 1980; Brown et al. 1985). These relationships probably do not relate well to duff moisture at the base of a tree, however. If duff burnout around trees is expected to be a major source of undesirable injury, actual duff moisture should be measured to predict consumption.

In the absence of methods to predict root injury and its consequences, only general rules can be given for prescription development. When duff is wet (ca. 120%) expect minimal root injury. If the duff is deeper than 10 cm and drier than about 35%, basal girdling may be a problem for all but the thickest barked trees. In deep-rooted trees expect little additional mortality due to root injury unless duff consumption is also expected to be greater than 10 cm. Expect shallow-rooted species to experience root injury in any prescription that calls for more than 3 cm of duff consumption.

Predicting and Controlling Stem Injury

Stem tissues are injured by heat conducted through the dead outer bark. For trees of a given bark thickness, injury depends primarily on the residence time of active flaming (Rothermel and Deeming 1980) and to a lesser degree the residual burnout. The factors controlling the duration of flaming are not well defined, but fuel size, arrangement, and moisture content appear important. The residence time for individual fuel elements increases at the rate of 3.15 min/cm of fuel diameter (Anderson 1969). To minimize the duration of stem exposure to high temperature it is necessary to minimize the consumption of the larger woody fuels near the tree.

Because the duration of burning depends on fuel amount, distribution, and moisture, conceivably a prescription could be developed to minimize injury in any tree. In the Interior West, however, there appear to be practical limits. Trees with less than 0.2 cm of bark will likely die in any fire vigorous enough to encircle them. Trees with 0.2-0.5 cm of bark can resist cambium injury in short duration surface fires. In most operational burns in natural fuels the minimum bark thickness necessary for consistent cambium survival is around 1.0 cm. Prevention of excessive cambium injury during slash burning requires at least 2.0 cm of bark. Our data indicate that less than 5% of the cambium is killed in operational slash burns when bark is thicker than 4 cm. Injury beneath thick bark, except at the root crown, is exclusively associated with burnout of logs, so it is not advisable to burn with heavy fuels on more than one side of a tree unless they are too wet to burn effectively. Concentrations of logs may burn independently of smaller fuels and at moisture contents above 20%. Consumption of individual logs, however, should be minimal above 20%.

Quantitative methods for predicting how much heat a stem will receive during burning are unavailable, so only rough estimates can be given. The primary fuels of concern are those within 1 m of the tree. More distant fuels generally cause problems only when concentrated into "jack-pots" (Vines 1968) or when backing fires are used on steep slopes. If the fuels are mostly grasses, forbs, and loose needle litter, expect surface fires up to 2 minutes in duration. If downed woody 1-hour time-lag fuels are also present, expect the duration of burnout to be about 4 minutes. If considerable 10-hour time-lag fuels are present, expect the duration to be about 10-12 minutes. If there are enough 100-hour time-lag fuels (diameter 2.51-7.6 cm) to burn independently of finer fuels, expect a duration of 20-30 minutes. The 1000-hour time-lag fuels (diameter 7.61 cm) are usually only a problem if they are against the bole or if clumped nearby. Most of these burn out within 1 hour. These estimates can be used with bark thickness equations (Ryan 1982; Ryan and Reinhardt 1988) and the approximate heating rate of 3 min/cm of bark thickness (Ryan 1982; Peterson and Ryan 1986) to identify potential fuel situations that can lead to excessive cambium injury.

Modifying Fire Behavior

Prescription development is often an iterative process. For example, if after having developed a preliminary burn prescription expected mortality is unacceptable, it is necessary to either modify fire behavior or accept less than optimal survival. The latter is often necessary in multiple-objective burns.

Fire behavior is modified either by changing the amount of available fuel or the way it is ignited. The amount of available fuel can be modified either by changing the total fuel amount (e.g., modify the harvesting or utilization standards, firewood sales, yarding unmerchantable material (YUM)), the moisture content of one or more elements of the fuel complex, or the prescribed weather conditions.

Diurnal changes in fine fuel moisture, air temperature, and wind speed will modify crown scorch. If surface fuels are ignited, however, the duff beneath them will likely burn about as well at night as in the day. Thus, diurnal changes in fine fuel moisture or changes in the ignition pattern are not likely to affect duff consumption unless they result in a patchy burn. Diurnal changes in temperature are not likely to significantly affect duff burnout, but light wind may improve it somewhat.

Duff moisture content changes slowly. If duff moistures are out of the prescribed range, substantial wetting or drying must occur before duff consumption and potential root injury are significantly affected. Usually, rains of 1-2 cm are needed to initiate significant wetting of the duff mound beneath the tree. Rainfall amounts approaching one-third of the depth of the duff are needed to rehydrate dry duff enough to minimize burning. Removal or wetting of duff around tree bases is not practical in most situations but can be applied to high-value trees.

Several methods are available to reduce stem injuries. The most obvious is to burn when 10-, 100-, and 1000-hour fuels are sparse or too wet to burn. This often results in reduced burning opportunities or conflicts with other burn objectives or both. Other alternatives include removing woody fuels from around the tree and treating fuels with fire retardant chemicals, foam, or water. Ryan (1989) compared the effectiveness of three treatments in limiting cambium injury in mixed conifer stands in northern Idaho. Treatments were 1) application of fire retardant to the lower stem and fuels within 1.0 m of the tree, 2) similar application of foam, and 3) removal of all woody fuels within 1.0 m. Treatment effectiveness varied by bark thickness (i.e., species and diameter) and fuel conditions. Application of fire retardant reduced cambium injury to one-half the level of untreated trees. Foam reduced injury by approximately one-fourth, and fuel removal was only marginally better than untreated. Removing fuels for 1.0 m around trees was ineffective for thin-barked trees. Ground application of fire retardants was not effective against large concentrations of logs or deep dry duff or both. Fuel removal and foam application were not effective when nearby large fuel concentrations resulted in long duration heating unless bark was thick (approximately >3 cm).

If large concentrations of 1- and 10-hour time-lag fuels are expected to cause undesirable injuries, it is best to burn under marginally high moistures unless only a few trees require clearing. The 100-hour time-lag fuels are the primary source of injury in moderately thick-barked trees. These fuels should be removed if they occur on more than one side unless bark is thicker than 2-3 cm. The 1000-hour time-lag fuels should be removed if they occur on more than one side and are dry enough to burn. It is difficult to say just how far to clear around a tree. Economics often dictate how much mitigation is possible. Usually 1.0 m is sufficient, but that depends on the amount of fuel and the thickness of the bark. The thinner the bark and the heavier the available fuel the farther the fuel must be moved. Always move the fuel to the side, never up hill or down hill or on the windward side. Ryan (1982) gives additional guidance on fuel removal.

Ignition patterns can be modified to either increase or decrease the amount of fuel that is burning at any one time. This modifies fire behavior around the tree, potentially altering the injuries received. For example, strip head-fire intensities can be reduced by igniting one strip at a time and making the width of the burn strip less than the maximum flame zone depth (i.e., if a free burning head-fire has, or is predicted to have, a 4.0-m flame zone depth, burn strips of less than 4.0 m will reduce flame lengths). This can reduce crown scorch. Several strips ignited close together in time and space increase surface fire intensity, which increases crown scorch and may cause stem injury. Backing fires result in lower surface fire intensity but longer duration. This can result in lower scorch height but greater bole damage. When backing fires are used on steep slopes, the uphill side receives heat from the approaching backing fire, from the burnout of fuels at the base, and from the burnout of fuels below the tree. This "triple dose" of heat is often injurious, particularly high on the bole. Tree-centered spot firing (Weatherspoon et al. 1989) has been used to reduce bole heating and resulting injury. Flanking fires result in varied fireline intensities. Initially, intensity is relatively low but increases as strips converge. This may be useful for increasing the amount of diversity on a burned area, but because it is difficult to predict and control the effects, it is rarely used.

CONCLUSIONS

Successful underburning requires an understanding of how fuels, weather, fire behavior, and the current stand conditions interact to result in fire injuries. Translating long-term management goals into prescribed fire objectives requires an understanding of how injuries affect survival and growth. There are many unquantified relationships and no one best approach to prescription development. Prescriptions are continually revised and refined as knowledge and experience are gained. The process is both an art and a science.

The conceptual framework illustrated in Figure 1 serves as a guide for prescription writing. It is also useful for identifying knowledge gaps and formulating studies for developing improved management guidelines. At the Intermountain Fire Sciences Laboratory we are attempting to establish direct relationships between the fire environment and fire characteristics. We are also attempting to establish predictive relationships between fire behavior and fire injury. We have examined and modeled survival of fire-injured trees. We have also begun examining the physiology and growth responses to fire injury. This has helped identify acceptable levels of fire injury. At this point it is not possible to give managers specific recommendations for all aspects of prescription development because there is still as much art as science involved in the process. As we learn more about the relationships illustrated in Figure 1, managers will be better able to define prescribed fire objectives that are consistent with their management goals.

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USE OF PRESCRIBED FIRE FOR DWARF MISTLETOE CONTROL IN LODGEPOLE PINE MANAGEMENT

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ABSTRACT

Wildfire has long been thought to be a primary factor responsible for limiting the spread and intensification of dwarf mistletoe (*Arceuthobium* spp.). The application of prescribed fire has been considered as a viable method for controlling dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) in lodgepole pine (*Pinus contorta* Dougl.) forests. In an attempt to evaluate the effectiveness of fire for regulating disease infection and spread, five heavily infected lodgepole pine stands in southwestern Colorado were burned during summer and fall conditions. This study reports on the effectiveness of these prescribed fires in terms of disease reduction, host mortality, fire behavior, and fuel load reductions. Management recommendations concerning prescribed fire use for this purpose are discussed.

INTRODUCTION

Historically, lodgepole pine forests have been important for a multitude of purposes. Within the last 25 years, however, this species has attained substantial stature as a source for commercial forest products. A variety of ecological factors affect lodgepole pine and cause growth loss, mortality, and changes in stand structure and composition. The most significant damaging agent attacking lodgepole pine is dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Englem.) (van der Kamp and Hawksworth 1985). This disease is present throughout the entire range of its host, and estimates show that nearly 50-60% of all stands in the Rocky Mountains are infected (Drummond 1982).

Effects of dwarf mistletoe infection on lodgepole pine trees are many and varied. Mistletoe is an obligate parasite, and it appropriates all necessary water, minerals, and other nutrients at the expense of uninfected portions of the host. Damage to infected trees is generally manifested as growth loss (both diameter and height) and increased mortality. Other major impacts include reduced cone and seed crops (Schaffer et al. 1983), diminished seed viability, reduced wood quality (Piirto et al. 1974; Dobie and Britneff 1975), and increased susceptibility to other damaging agents.

In addition to periodic and chronic pest infestations, lodgepole pine forests are subjected to the periodic occurrence of fires of varying intensity. The influence of fire on lodgepole pine establishment and development is well documented (Clements 1910; Mason 1915; Smithers 1961; Wellner 1970; Brown 1975; Perry and Lotan 1979; Lotan et al. 1985). Fire, lodgepole pine, and dwarf mistletoe have diverse interrelationships (Alexander and Hawksworth 1975; Hawksworth 1975; Wicker and Leaphart 1976; Zimmerman and Laven 1984, 1987), with wildfire considered to be the most likely natural factor controlling this pathogen (Hawksworth 1961; Taylor 1969; Baranyay 1970; Heinselman 1970; Alexander and

Hawksworth 1976); however, the influence of fire on dwarf mistletoe survival and distribution is neither fully understood nor well documented (Hawksworth 1961, 1975; Wright and Heinselman 1973).

Progress toward effective control of dwarf mistletoe in lodgepole pine forests through direct treatment has been relatively slow. In dwarf mistletoe infected stands, three possible control alternatives exist: no action, reduction of infection to tolerable levels, and stand replacement (Dooling and Brown 1976). The latter two have traditionally been accomplished, with varying degrees of success, through direct physical removal of infected trees or their parts or by chemical treatments.

Application of prescribed fire is a treatment that has received little attention from researchers but may be suitable in some lodgepole pine stands (Alexander and Hawksworth 1975). Prescribed burning was proposed first as a possible treatment for mistletoe control early in this century (Weir 1916). Since then, numerous researchers have advocated fire as a supplemental control method (Gill and Hawksworth 1961; Beaufait 1966; Weaver 1967; Kiil 1969; Baranyay 1970, 1975; Muraro 1978a, 1978b; Smith 1971; Koonce and Roth 1980).

In most lodgepole pine forests, past use of prescribed fire has been restricted to hazard reduction and site preparation functions in conjunction with timber harvesting and subsequent regeneration (Crane and Fischer 1986). Understory burning has received limited application, but broadcast burning has been utilized extensively for a variety of objectives (Kiil 1969; Baranyay and Smith 1972; Jones 1974; Lotan and Perry 1977; Brown and Lotan 1982; Lotan 1982; Schmidt 1982; Zimmerman 1982). Prescribed fire may be useful in dwarf mistletoe infected lodgepole pine stands in two ways: to provide an economical and effective means of eliminating residual trees in logged-over areas; and to destroy entire stands where infection is so severe that the stands are unmanageable (Ainscough 1971; Alexander and Hawksworth 1975; Muraro 1978a, 1978b).

The objective of this study was to improve our understanding of the interactions of fire and dwarf mistletoe in lodgepole pine forests. Specifically, we examined the effectiveness of prescribed fire in controlling the proliferation of dwarf mistletoe in lodgepole pine stands.

REVIEW OF SOUTHWESTERN COLORADO DWARF MISTLETOE CONTROL PROJECT

Broadcast burning guidelines for lodgepole pine slash (Quintilio 1972; Zimmerman 1982) may have application in the elimination of residual infected trees following timber harvesting. There are no descriptions of or guidelines for the eradication of entire infected stands, however. The case study discussed in the following section represents a cooperative effort between the USDA Forest Service (Rocky Mountain Forest and Range Experiment Station; Rocky Mountain Region, Forest Pest Management; and Gunnison National Forest) and Colorado State University. Prescribed fires were utilized in this project to ameliorate dwarf mistletoe infected lodgepole pine stands.

Stand and Area Description

Areas of the Gunnison National Forest in southwestern Colorado served as the study location. Specific treatment units were located in the Taylor Park area of the Taylor River Ranger District. Taylor Park, located approximately 61 km northwest of Gunnison, is a high-elevation mountain valley bounded on the north and east by the Continental Divide and completely surrounded by mountains. Study site elevations range from 2900 to 3100 m, and slopes vary from nearly flat to moderately steep on a variety of aspects.

Vegetation of this area can be grouped into two broad categories: shrub-grass openings and coniferous forests (after Langenheim 1962). Coniferous forests in the area are dominated by lodgepole pine, although Engelmann spruce (*Picea engelmannii* Parry), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), quaking aspen (*Populus tremuloides* Michx.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) also occur. Limber pine (*Pinus flexilis* James) and bristlecone pine (*Pinus aristata* Engelm.) are present as scattered individuals.

In a related study, Zimmerman and Laven (1984) reported that the lodgepole pine age-class distribution in the Taylor Park area was unexpected in that the majority of stands were concentrated between 101 and 125 years of age. Stands representing young and mature age classes were noticeably lacking. In this study the age of 50% of stands treated by prescribed burning were also between 101 and 125 years. Twenty percent were between 76 and 100 years in age, and no stands were found that were less than 25 years or older than 150 years.

Lodgepole pine stands selected for treatment by prescribed burning varied considerably in structure. Density of mature stems ranged from 713 to 2497/ha and seedling density ranged from 218 to 6600/ha. Trees greater than 1.37 m in height had average diameters of 4.5-16.6 cm and total heights of 3.3-12.6 m. Tree crowns ranged from 2.7 to 8.5 m in length, from 0.93 to 2.18 m wide, and were from 0.64 to 5.92 m above the ground. Depth of duff layers prior to burning varied from nearly 3 cm to slightly more than 7 cm.

Methods

Five stands were selected for prescribed burning treatments. Stands selection was based on the following criteria: absence of timber harvesting activity; presence of dwarf mistletoe infection; no plans for intensive management; accessibility for fire control equipment; and presence of natural barriers or fuel breaks that facilitated prescribed burn control and safety. Stands ranged in size from 6 to 16 ha and contained a variety of age classes, size classes, densities, and downed-fuel accumulations.

Rectangular plots were used throughout the burn units. Preburn measurements documented site characteristics, overstory vegetational structure and composition, dwarf mistletoe infection levels, and downed woody fuel accumulations. Structure and composition were determined by measuring diameter at breast height, total height, live crown length, and distance to live crown base. Dwarf mistletoe ratings (DMR) were used to provide indications of infections levels. The six-class ratings system (Hawksworth 1977) was used to construct the dwarf mistletoe ratings.

Down and dead woody fuels were inventoried by the planar intersect technique (Brown 1974). Duff consumption was determined through the use of bridge spikes in a manner similar to depth of burn pins (McRae et al. 1979).

Prescribed fires were ignited by crews using handheld drip torches. Strip head firing was the primary firing technique employed in all burn units. Where necessary, backing fires were ignited as a means of burning out fuels between fire lines and the flaming perimeter.

Fire behavior was measured by individuals positioned as close to each plot as was safely possible. The time, flame length, and flaming zone depth were recorded as fires passed preestablished grid markers. In other situations, either the time was periodically called out and desired fire characteristics and time were recorded, or the fire front was sketched on maps at each defined time. Rate of spread of the flaming front was determined from recorded times and was used in conjunction with flame depth to determine residence time.

Weather observations during burning included dry and wet bulb temperatures (for relative humidity determination), wind speed, and wind direction. A standard array of 1.27-cm ponderosa pine fuel sticks were weighed to determine 10-h time-lag (TL) fuel moisture content (Deeming et al. 1977). Dead fuel moisture reference tables were used to determine 1-h time-lag (TL) fuel moisture contents (Rothermel 1983). Immediately prior to burning, dwarf mistletoe shoots, lodgepole pine foliage, and duff samples were collected to determine moisture content by oven-drying techniques (Norum and Miller 1984).

Following burning, stands were reinventoried to determine tree mortality, dwarf mistletoe infection intensity, downed woody fuel, duff consumption, and depth of burn. All stands were photographed before, during, and after the fires at permanent photo points.

Discussion of Prescribed Fire Effectiveness

Prescribed Burning Conditions

Prescribed burning was carried out under conditions commonly experienced during both summer and fall seasons. Four of the units were burned during September and October, and the remaining unit was burned during late June (Table 1). Air temperatures at the start of burning ranged from 13 to 26°C (Table 1). Relative humidity measured during burning did not drop to critically low levels. Minimum values ranged from 18 to 25% (Table 1). All burns were competed under conditions of low-to-moderate winds from favorable directions (Table 1).

Analysis of the dead and live fuel and duff layer moisture contents revealed the greatest variation in lodgepole pine foliage and duff layer moisture content among the fall burn units. Dead fuel moisture contents in the smallest category (1-h TL) were relatively low for all burns (Table 1). Dead fuel moisture contents in

Table 1. Date, time, weather, and fuel moisture conditions associated with the five prescribed fires

Item	Stand numbers				
	1	2	3	4	5
Date of burning	June 21/83	Oct. 7/82	Oct. 7/82	Oct. 7/82	Sept. 3/82
Start time of burning (MDT)[a]	1145	1030	1530	1300	1430
End time of burning (MDT)[a]	1600	1215	1645	1400	1905
Air temperature at start of burning (°C)	26	—	16	16	13
Air temperature at end of burning (°C)	24	—	18	16	18
Maximum air temperature during burning (°C)	27	—	24	16	25
Relative humidity at start of burning (%)	28	—	27	29	59
Relative humidity at end of burning (%)	29	—	18	27	35
Minimum relative humidity during burning (%)	25	—	18	27	22
Wind speed[b] at start of burning (km/h)	0-3	—	1.2	0-1.2	0-1.2
Wind direction[b] at start of burning	NW	W	W	SW	W
Wind speed[b] at end of burning (km/h)	0.0	—	0-4.4	0-2.1	0.0
Wind direction[b] at end of burning	—	W	W	SW	—
Maximum wind speed[b] during burning (km/h)	3.7	—	4.4	2.1	0.0
Dead fuel moisture content—1-h TL (%)	4.0	—	5.0	6.0	5.0
Dead fuel moisture content—10-h TL (%)	7.0	—	8.0	8.0	9.0
Dwarf mistletoe shoot moisture content (%)	171	122	131	—	130
Lodgepole pine foliage moisture content (%)	99	103	173	—	59[c]
Duff layer moisture content (%)	18	22	16	—	8

[a] MDT = Mountain Daylight Time.

[b] Wind speed and direction measured inside the stand at a "midflame" height.

[c] This value appeared excessively low but was accurate based on the methodology utilized in the study, which involved a composite sample of all needle ages. It is not known if this value was indicative of extremely low seasonal moisture content, a low moisture content associated with dying trees, or a combination of both.

the next larger particle size (10-h TL) were somewhat higher and exhibited a trend similar to that of the smaller size class fuels. Measurement of moisture content in live fuels indicated that dwarf mistletoe plants had the highest moisture levels during the early summer burn (Table 1). Moisture content of lodgepole pine foliage was highest on the treatment units burned later in the year and lowest during the September burn. Duff layer moisture contents varied considerably but showed no definitive trends other than being comparatively low during all burning periods (Table 1).

Types of Fires and Fire Behavior

Because of differing weather, fuel, and moisture conditions, each prescribed fire behaved somewhat differently. Fire behavior documentation was not complete for some of the burn units due to smoke and reduced visibility, concerns for personal safety, and speed of ignition. Fire behavior characteristics are listed in Table 2.

Stand 1 burned with a combination of heading and backing surface fires and passive and active crown fires. This unit was burned during the summer and resulting intensities were indicative of the relative dryness of fuels at this time of year. Portions of this stand were consumed by passive crown fires having flames extending to 20 m above the aerial fuel stratum (estimated from photographs taken at the burn). Other portions of the stand were completely engulfed by active crown fires.

Stand 5 was the first unit to be burned during the fall. This stand burned with variable fire intensities and fire types including heading and backing surface fires, and passive, active, and independent crown fires. The upslope portion of the unit was consumed by moderate to high intensity surface fires that frequently turned

Table 2. Range in observed and calculated fire behavior characteristics associated with the five prescribed fires

Stand plot number	Rate of spread[a] (m/min)	Flame length[a] (m)	Flaming zone depth[a] (m)	Fireline intensity[b] (kW/m)	Heat per unit area[b] (kJ/m²)	Residence time[b] (min)
1A	—[c]	—	—	—	—	—
1B	—	—	—	—	—	—
1C	—	—	—	—	—	—
2A	0.0 - 0.76	0.3 - 6.0	0.5 - 7.0	19 - 12 596	0 - 994 386	0.0 - 9.2
2B	0.0 - 0.58	—	—	—	—	—
3A	1.0 - 5.0	—	—	—	—	—
3B	0.0 - 1.4	1.0 - 4.0	0.5 - 4.0	258 - 5 225	0 - 223 930	0.0 - 2.9
4A	—	—	—	—	—	—
4B	—	—	—	—	—	—
5A	0.0 - 1.6	0.3 - 3.0	0.2 - 3.0	19 - 2 799	0 - 104 955	0.0 - 1.9
5B	0.0 - 0.5	0.2 - 0.8	0.3 - 4.0	8 - 159	0 - 19 076	0.0 - 8.0

[a] Observed.

[b] Calculated: Fireline intensity = 258 (flame length$^{2.17}$); heat per unit area = (60 × fireline intensity)/rate of spread; residence time = flame depth/rate of spread (from Rothermel and Deeming 1980).

[c] Dashed line indicates missing or incomplete observations. Observed fire behavior characteristics are given for surface fires and are not representative of crown fires.

into passive crown fires. These fires then torched individual or groups of lodgepole pine trees. The lower portion of the stand was ignited simultaneously with the resultant fire quickly becoming a moderate to high intensity surface head fire. Prior to reaching previously burned areas further up the slope, the surface fire spread into the aerial fuel stratum. Then, in the absence of excessive winds and a surface fire, an independent crown fire spread through the tree crowns and reached the top of the slope in numerous places. This situation may have been facilitated by the preheating of crown fuels caused by earlier surface fires and the relatively steep slope.

Stand 2 was ignited by strip head fires during midmorning hours and produced heading and backing surface fires and occasional passive crown fires. The surface fires ranged in intensity from low (in fact, many areas did not even burn in this stand) to moderate as indicated in Table 2. Passive crown fires did not occur frequently. In situations where severely infected trees possessed witches'-brooms close to the ground, fires were able to spread vertically into the tree crown.

Strip head firing was again used as the principal ignition pattern in Stand 3. This stand possessed substantial quantities of dead fuel and tree regeneration in addition to the overstory. Type of fires occurring here included heading and backing surface fires and high intensity passive crown fires. Nearly all of the upslope portion of the stand was consumed by the high intensity passive crown fire. The lower slope portion of the stand burned with more variability in fire behavior. Areas in this part of the stand either did not burn at all or were burned by slow-moving, low-intensity backing fires, heading surface fires, and passive crown fires. The crown fires in this portion of the stand were confined to scattered pockets of individual trees or groups of trees. Flames ranged from 5 to 10 m above the tops of tree crowns.

Stand 4 was burned while preparations for burning were taking place in other stands. Thus, no observations were taken during the actual burning. The unit was situated on top of a small hill, and the desired ignition technique involved ring center firing; however, the center fire did not create the updrafts necessary to draw perimeter fires inward. Parts of the center fire turned into a surface head fire that quickly developed into an active crown fire and moved up the slight slope and over the hilltop before breaking down into a surface head fire. Other areas in this stand did not burn, as the backing fires ignited along the perimeter only moved through areas where surface fuels were abundant. This resulted in an extremely erratic burn pattern. In areas where the fire did not burn, a sizable portion of the existing trees and herbaceous vegetation suffered mortality due to heat generated by the crown fire in other parts of the stand.

Photographs indicated that Stand 1 probably had the greatest flame production over the largest area. Stand 5 exhibited the most extremes in fire behavior during the independent crowning run that occurred late in the day. In all units, the absence of winds contributed markedly to control of the fires and low-to-moderate rates of spreads (Table 2).

Fuel Consumption and Duff Reduction

Prior to prescribed burning, the accumulation of downed woody fuels on the forest floor was generally heavy in all stands (Fig. 1). Total loadings ranged from nearly 60 to 85 t/ha. The majority of this material was composed of fuel particles in the larger size classes (7.62+ cm), presumably a result of dwarf mistletoe-caused mortality of lodgepole pine trees.

The prescribed burns significantly lowered total fuel loadings in all but one of the stands (Fig. 1). In Stand 4 the fire resulted in a 50% reduction of fuels in the smallest size class (0-0.6 cm), but the remaining fuel size classes were observed to have either no change or slight increases in postburn fuel weight per area. Increases in total fuel loadings were attributed to increases in weight of larger size classes resulting from the addition of previously standing stems to the surface fuel bed.

In all other stands prescribed burns substantially reduced fuels in all size classes. Fuel consumption was greatest in those stands having the least amount of incomplete or patch-type burning.

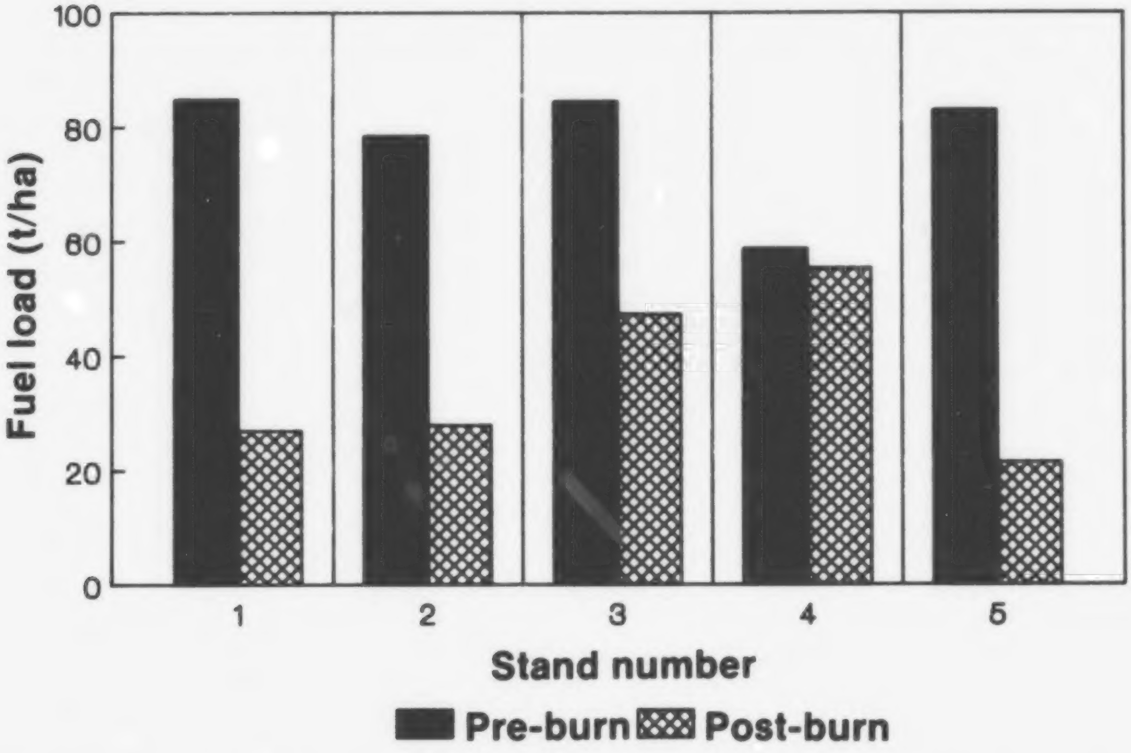

Figure 1. Accumulation of total downed woody fuel loading before and after prescribed burning.

The amount of duff consumed by the prescribed burns was generally high in all stands. Two plots (2B and 3B) had less than 45% of the duff layer removed by fire. These two plots also had the lowest amount of duff prior to burning. All remaining plots had between 60 and 70% of the duff layer consumed by fire, regardless of preburn depth. Plots 1B, 1C, and 5A had the greatest proportion of the duff layer consumed by fire (73, 69, and 70%, respectively) (Fig. 2).

Tree Mortality

The major trend following prescribed burning was the drastic reduction in mature live stem density. This reduction was a direct result of tree mortality from crown scorch, crown consumption, and bole damage. One hundred percent mortality was achieved in two of the plots, and one had 99% of the trees killed (Fig. 3). Four other plots had tree mortality greater than 75% (Fig. 3). The greatest tree mortality occurred in plots 1C, 4B, and 5A (Fig. 3). These plots were not documented as having the highest levels of fire intensity (some were not able to be measured) (Table 2); however, the levels of intensity attained by fires in these stands were apparently maintained over larger areas, which caused greater tree mortality. These plots were also subjected to both passive and active crown fires. Those plots having higher levels of fire intensity (2A, 3B) (Table 2) did not exhibit excessive tree mortality (Fig. 3). Apparently in these stands fires of high intensity levels did not occur over large areas. Instead,

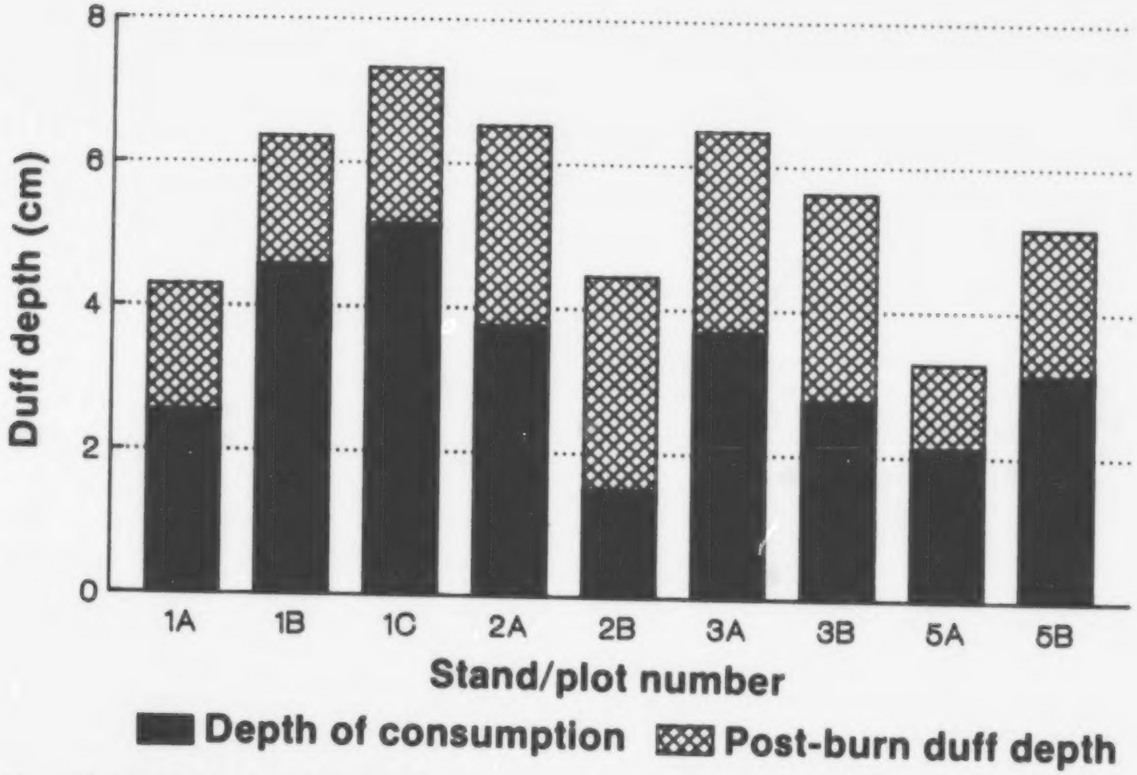

Figure 2. Pre- and postburn duff depths, and depth of duff consumption by treated stand/plot. Preburn duff depth is equal to the sum of the postburn depth and depth of burn (i.e., the top of each bar).

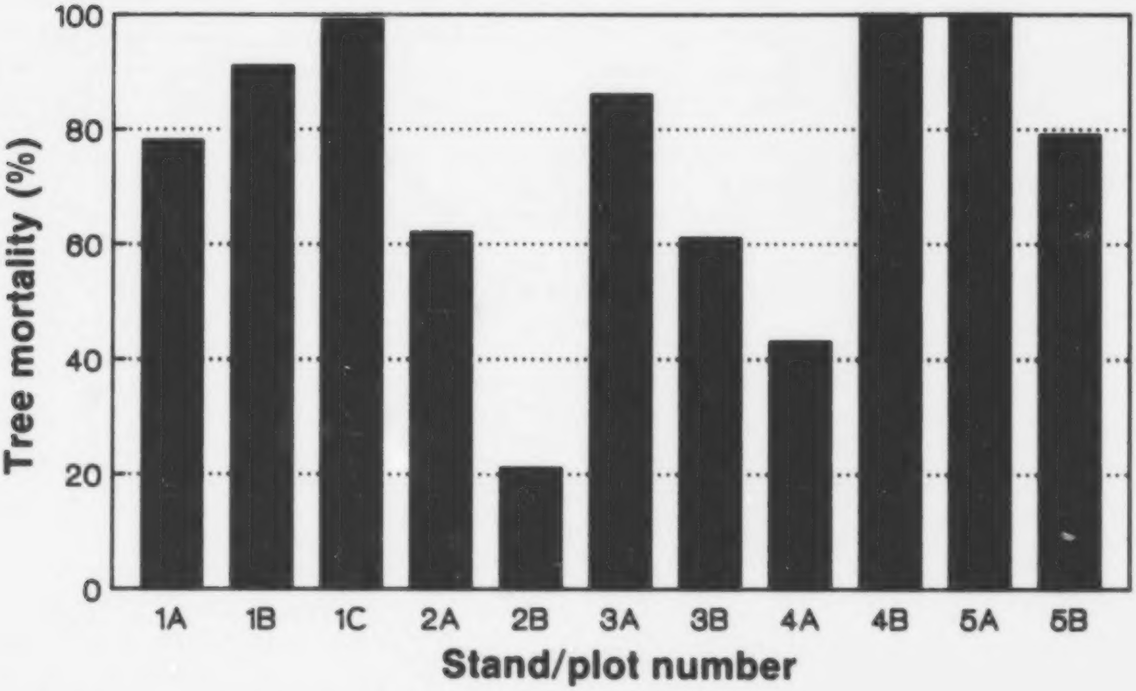

Figure 3. Postfire tree mortality by treated stand/plot.

high-intensity fires must have been confined to relatively small areas while the majority of the stands were exposed to fires having lesser intensity levels. The lowest fire intensities and most incomplete burns were observed in plots 2B and 4A. As a result, these plots had the lowest percent tree mortality.

Additionally, postburn measurements revealed slight increases in average tree diameters and total height in most but not all plots; reductions in length of live crowns; increases in distance from the ground to crown bases; and no discernible trends in crown widths. Increases in average tree diameters and heights may have occurred because of the relatively greater susceptibility to fire damage of smaller trees. In plots where surface fires predominated, thinner bark and lower crown base of smaller trees would have caused greater mortality of these trees than of larger, thicker-barked trees. In this case, the average postburn stand characteristics would reflect larger tree sizes. If crown fires only occurred through part of the stand, possibly the fire consumed larger trees while leaving areas of smaller trees, resulting in smaller average tree sizes following the fire.

Dwarf Mistletoe Infection Intensity

Dwarf mistletoe infection was present in all stands at relatively high levels prior to prescribed burning. When compared by individual DMR class intervals, the greatest percentage of stands were infected at the second to highest level (DMR = 4.1-5.0), followed by the highest level (DMR = 5.1-6.0), and next lowest level (DMR = 3.1-4.0) (Fig. 4). All treated lodgepole pine stands contained dwarf mistletoe infection with intensities greater than 2.1 as reflected by DMR (Fig. 4).

In this project, prescribed burning has the net effect of causing an overall reduction in the intensity of dwarf mistletoe infection (Fig. 4). With the exception of two DMR class intervals (DMR = 0 and 3.1-4.0),

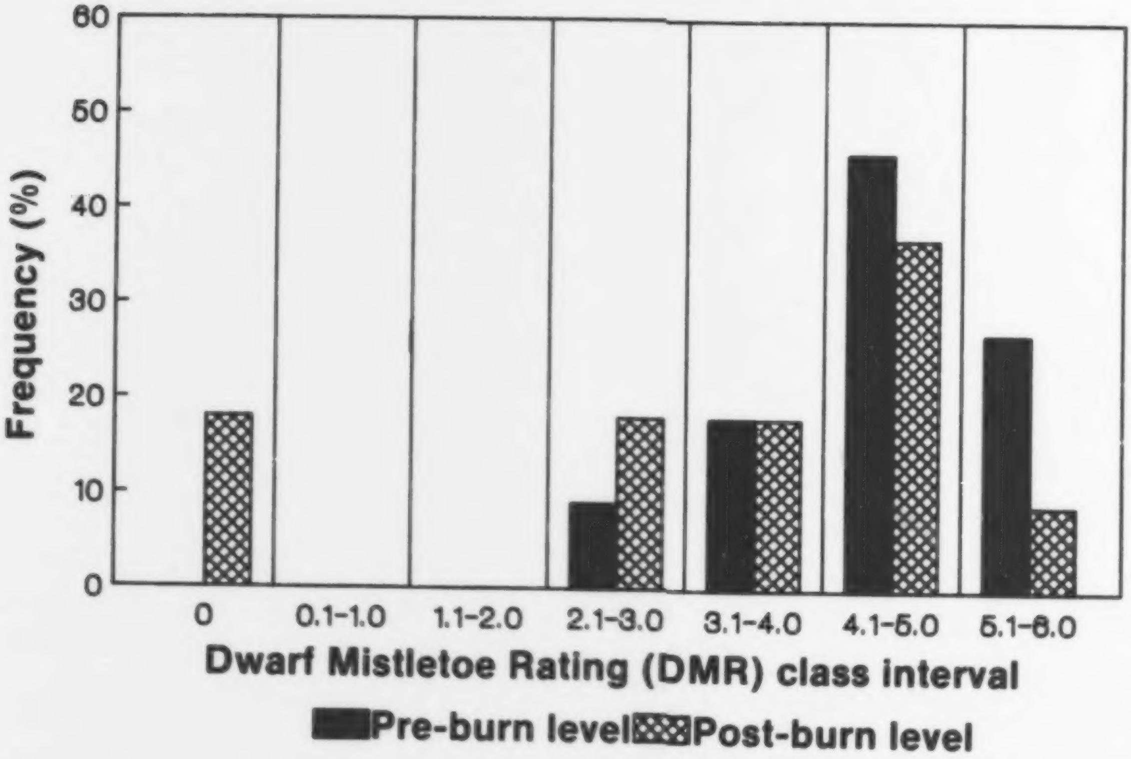

Figure 4. Distribution of dwarf mistletoe infection intensity in lodgepole pine stands before and after prescribed burning.

the percentage of stands in each infection category was reduced (Fig. 4). The proportion of stands in the lowest DMR class interval increased because 100% mortality sanitized some of the stands.

IMPLICATIONS FOR MANAGEMENT

Fire can affect dwarf mistletoe both directly and indirectly. Shoot mortality from direct fire effects occurs when immediate plant death is caused by tissue oxidation and reduction to ash or by destruction of host trees (Wicker and Leaphart 1976).

Indirect effects of fire on dwarf mistletoe are not well understood. Exposure of pathogen seeds to smoke has been reported to have variable effects ranging from beneficial to detrimental (Zimmerman and Laven 1987). The influence of heating on dwarf mistletoe survival is not clear but indications are that exposure to high temperatures for certain time periods are lethal to dwarf mistletoe plants and seeds[1].

Fire has been the most important natural factor in control of lodgepole pine dwarf mistletoe (Baranyay 1970). Most effective control of this disease occurred when host trees were destroyed by high intensity fires that consumed all or nearly all of entire stands.

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[1] Alexander, M.E. 1974. Heat tolerance of *Arceuthobium* spp. Unpublished report on file with U.S. Dep. Agric., For. Serv., Rocky Mt. For. Range Exp. Stn., Fort Collins, Colorado.

The application of prescribed fire can be utilized as a technique to simulate the role of wildfire in controlling this pathogen. Consequently, prescribed fire will be most effective when all or nearly all of the stand is destroyed. Accomplishment of this goal is not an easy task; it requires detailed preplanning and precise implementation, and may not be the most suitable or desirable treatment technique in all stands.

The ease with which prescribed fires of moderate to high intensity can be conducted is directly influenced by the amount of fuel to be burned, stand structure, and weather conditions during burning. Dwarf mistletoe infection tends to cause increases in surface fuel accumulation that can promote higher fire intensities. In addition, infection by this parasite may affect the type of fire that occurs in a given stand. Long-term infections can alter age class distribution. Areas of infection epicenters become more open due to increased mortality and eventually support abundant regeneration. Accelerated witches'-broom formation and duff buildups create fuel ladder situations and enhance vertical fuel continuity. As a result, passive crown fires are more likely to develop from surface fires. In addition, the likelihood for differential fire intensity to occur within the stand increases. The resultant burn will consist of patchy, incomplete fuel consumption and tree mortality.

Increased surface fuel loads, fuel ladder situations, and fuel moisture conditions common to summer and fall seasons make control of these types of prescribed fires difficult. Since the objectives involve achieving 75-100% mortality, burning under conditions more favorable to crown fire development is necessary. Successful project completion, therefore, requires complete planning and careful implementation.

Wind speed is probably the most critical factor in maintaining control of prescribed fires in this situation. If surface fuel loads are adequate, burning under conditions of low winds can result in high intensity surface fires and passive crown fires that will achieve objectives. Increasing wind speeds, however, are conducive to active crown fire development. Higher winds also increase the potential distance of spot fire occurrence. Spot fire development is a significant factor leading to loss of control, especially during summer time conditions.

With little or no winds, prescribed fires can be contained with construction of minimal firelines. Larger, mechanically constructed lines may be necessary if winds increase or originate from unfavorable directions.

Not all lodgepole pine stands are well-suited for fire application. Prescribed fire may be undesirable in stands lacking good access, possessing commercial wood product values, adjoining areas of higher value timber, or having low surface fuel accumulations. Where nonuniform stand structure and heavy dwarf mistletoe infection are present, variations in fire behavior, incomplete fuel consumption, and patchy tree mortality can be expected, making accomplishment of objectives much more difficult. Follow-up treatments by mechanical, chemical, or physical methods are necessary if burning causes incomplete tree mortality.

In the southwestern Colorado project, prescribed fire was successful in achieving the desired levels of host tree mortality. In some stands, however, less than 100% tree mortality occurred. But, even when follow-up removal of residual trees by physical means was required, cost-efficiency was still greater than when only mechanical eradication methods were employed throughout entire stands.

Fuel hazards can accumulate following prescribed burning. These situations are generally not an immediate problem but increase in severity over time. Following mechanical treatments, fuel buildups can also result but reach dangerous levels almost immediately. Posttreatment broadcast burning can control slash but will destroy any newly established seedlings and remaining seed supply. Mechanical stand eradication can be followed by machine piling after lodgepole pine cones have opened and dispersed seeds. Costs associated with this type of treatment rapidly escalate for several reasons. First, heavy equipment has to traverse the stand area at least twice to complete operations. Secondly, equipment may have to be transported from the site and back again between eradication and piling operations. Thirdly, transportation costs and wages of personnel involved in the entire project mount rapidly as the length of time required for project completion increases.

Managers responsible for dwarf mistletoe control in lodgepole pine management should consider prescribed burning as a viable, cost-efficient treatment technique. Decisions on when and where to apply this treatment should be carefully weighed. In appropriate stands, project planning can be followed by careful implementation and result in accomplishment of the desired objectives.

SUMMARY

Dwarf mistletoe is widespread in lodgepole pine forests of the western United States and Canada, but the magnitude of the problem to forest management has only recently been recognized. Silvicultural techniques, such as clear-cutting and sanitation thinnings have been effective in controlling dwarf mistletoe in many situations. In other situations such as in heavily diseased unmerchantable stands, however, supplemental control techniques such as prescribed fire are needed.

Since wildfire has been the primary natural factor limiting dwarf mistletoe proliferation, prescribed fire has been considered as a possible treatment technique. Application of controlled fires that burn under intensities likely to cause 75-100% mortality of host trees can be successful and highly cost-effective. This goal is not easily accomplished, however, and requires detailed preplanning and precise implementation and is not the most suitable or desirable treatment technique in all lodgepole pine stands.

Prescribed burning is by no means the sole solution for dwarf mistletoe control in lodgepole pine forests. Instead, it is an alternative method capable of achieving pathogen reduction but causing host tree mortality. As with any type of dwarf mistletoe treatment program, prescribed burning will result in the most effective control if conducted over large areas for longer time periods rather than being occasionally administered over small areas.

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PRESCRIBED FIRE EFFECTS IN SAGEBRUSH-GRASSLANDS AND PINYON-JUNIPER WOODLANDS

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ABSTRACT

The pinyon-juniper woodlands and the sagebrush-grasslands, with a combined area of over 90 million ha, comprise a major portion of the rangelands in western North America. During pristine times fire played an important role in these vegetation types. The role of fire has changed significantly in the historic period. Changes in fire occurrence have resulted from fire suppression, livestock grazing, and the breaking of the fuel continuity with roads and other developments. In general, fire is less common today than it was prior to Euro-American settlement, but in some areas it is more frequent. This alteration of the fire frequency has resulted in major successional changes in the vegetation. Prescribed fire is currently used to counter the successional changes and to achieve a variety of land management objectives in both vegetation types. While herbaceous productivity is often increased following fire, there are many problems associated with the use of prescribed fire in these communities. Low amounts of fine fuels, high populations of exotic annual plants, and severe environmental conditions create challenges for the land manager when planning prescribed fires.

INTRODUCTION

The pinyon-juniper association is a widespread vegetation type occurring throughout western North America (Fig. 1). The term "pinyon-juniper" is commonly used but juniper (*Juniperus*) species are more abundant than pine (*Pinus*) species throughout the range, and in many areas the pine species are absent. The majority of the western juniper (*J. occidentalis*) stands occur without a pine codominant. West et al. (1975) indicate the association occupies approximately 32.5 million hectares. This includes western juniper communities of the northwestern USA, the pinyon-juniper association of the Great Basin and Southwest, and the juniper woodlands of western Texas. This area, however, does not include the juniper-oak woodlands of Mexico and the Rocky Mountain juniper (*J. scopulorum*) woodlands of Wyoming and Montana.

The sagebrush-grasslands occupy much the same general region as the pinyon-juniper and juniper woodlands north of 37°N latitude (Fig. 1). There are more extensive areas of sagebrush-grassland vegetation in Wyoming, Montana, southern Alberta, central Washington and southern British Columbia. Estimates of the total area dominated by sagebrush (*Artemisia* spp.) vary, but the figure of 58 million hectares developed by Branson et al. (1967) from Kuchler's (1964) vegetation map is probably a close estimate (Tisdale and Hironaka 1981). Regardless of the estimate used, the sagebrush-grasslands comprise the largest rangeland vegetation association in North America.

The pinyon-juniper and sagebrush-grass vegetation types are composed of a variety of dominant species as would be expected given the wide range of the types. Major tree species include singleleaf pinyon (*Pinus monophylla*), pinyon (*P. edulis*), oneseed juniper (*Juniperus monosperma*), Utah juniper (*J. osteosperma*), alligator juniper (*J. deppeana*), Rocky Mountain juniper, and western juniper. A large number of sagebrush species occur within the region, but the most common species are big sagebrush (*Artemisia tridentata*) (several subspecies and forms), silver sagebrush (*A. cana*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), threetip sagebrush (*A. tripartita*), Bigelow sagebrush (*A. bigelovia*) and early low sagebrush (*A. longiloba*). Understory species are similar in the pinyon-juniper and sagebrush-grass vegetation types and comprise a variety of shrubs and cool-season herbaceous species. In the southern portion of the associations, warm species become more abundant

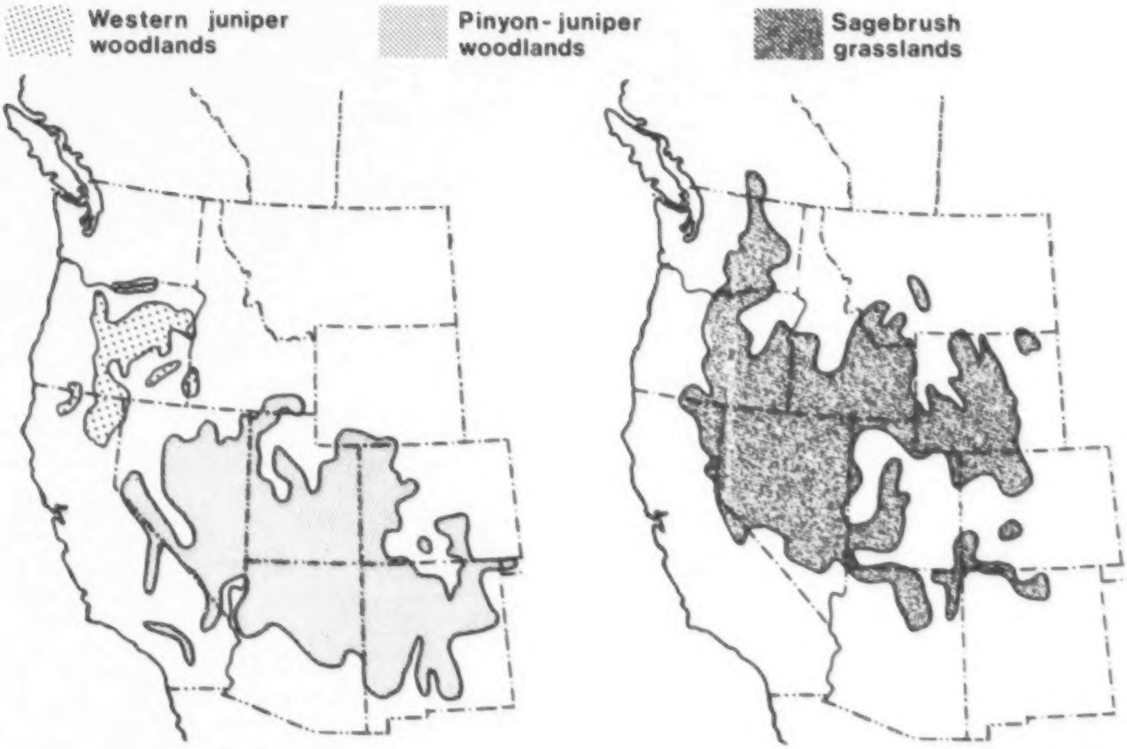

Figure 1. Distribution of western juniper woodlands (left, light shading), pinyon-juniper woodlands (left, dark shading) and sagebrush grasslands (right) in western North America.

in the communities. Comprehensive reviews of the understory species are written in Tisdale and Hironaka (1981) and Wright and Bailey (1982). Additional information on the effects of fire on associated species can be found in Bunting (1985), Wright (1985), Everett (1987), Bunting et al. (1987), and Bunting (1987).

"NATURAL" ROLE AND OCCURRENCE OF FIRE

Fire was common in most pinyon-juniper woodlands and sagebrush grasslands prior to Euro-American settlement. It is difficult to precisely determine the fire history because of the lack of suitable species to record the occurrence of fire; however, most studies agree that the fire-free interval (FFI) has increased, i.e., fires are less frequent, since pristine times (Houston 1973; Burkhardt and Tisdale 1976; Wright and Bailey 1982). The reduction of fire has been caused by active fire suppression and domestic livestock grazing, which reduces fine fuels. Many of these semiarid communities naturally produce low amounts of herbaceous fuels, and any removal by herbivores can severely limit the ability to carry and sustain a fire. With fewer fires, juniper and pinyon have expanded into adjacent vegetation types, and tree density has increased on sites where they originally occurred. The impact of fire suppression on sagebrush is less clear. Some authorities insist that much of the current area dominated by sagebrush was originally grassland (Weaver and Clements 1938; Cooper 1953; Hull and Hull 1974; Barbour et al. 1980). Most recent research indicates that sagebrush is the climax species on most of its present-day range and that invasion into other vegetation types was uncommon (Daubenmire 1970; Harniss and West 1973; Zamora and Tueller 1973; Mueggler and Stewart 1980; Tisdale and Hironaka 1981; Hironaka et al. 1983). Sagebrush density has increased on many sites where it formerly occurred. Invasion into adjacent vegetation types is primarily limited to the grasslands on the eastern edge of its range (Tisdale and Hironaka 1981).

The introduction of exotic annuals, particularly cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*), has modified the role of fire in the sagebrush-grass ranges. Prior to the introduction of annuals, insufficient fine fuels often limited fire spread in sagebrush communities. After the reduction of herbaceous perennials in big sagebrush communities, the understory often remained depleted of plants and completely dominated by sagebrush. These communities could remain stable for long periods of time (Tisdale et al. 1969). The introduction of annuals increases the fuel load to the point where the site can carry a fire. Burning reduces sagebrush competition, allowing the annuals to flourish. This prepares the site for repeated fires. The incidence of wildfires increases, and eventually the site is completely converted to an annual grassland (Young and Evans 1978). Some sites now dominated by annuals may have an FFI of less than 5 years. The time period is not adequate for the sagebrush to become established and reach reproductive maturity. Repeated fire has removed sagebrush from extensive areas throughout the Great Basin and Columbia River drainage area.

USE OF PRESCRIBED FIRE IN VEGETATION MANAGEMENT

Currently, prescribed fire is commonly used as a management technique in pinyon-juniper woodlands and sagebrush-grasslands. The most prevalent objective is to control the establishment of juniper and shrubs and to increase herbaceous production on the site for wildlife and livestock grazing. Control of shrubs will normally increase the productivity of the herbaceous component of the community. Increases in herbaceous production of over 600% have been reported for pinyon-juniper (Aro 1971; Clary and Jameson 1981). It may take over 300 years for a climax stand to regenerate (Erdman 1970), and substantial control of the trees may last for over 50 years (Barney and Frischnecht 1974). Herbaceous cover declines linearly as tree overstory develops (Tausch et al. 1981). Seed production of understory species also declines rapidly (Koniak and Everett 1982; Everett and Sharrow 1983); this is reflected in a depletion of seed reserves in the soil. The reduction of herbaceous plants and their seed reserves results in low increases in forage following burning on sites that have greater than 20% canopy coverage of pinyon or juniper. Stands with low levels of tree cover (%) and higher amounts of perennial grass cover respond quickly. Those with high levels of tree coverage are often invaded by annuals following the fire if perennials do not quickly occupy the site. The annuals may prevent an abundant perennial herb community from developing.

Sagebrush grassland herbaceous production may increase 100% or more following burning when compared to the initial herbaceous biomass (Harniss and Murray 1973; Peek et al. 1979). The length of time forage production is increased varies considerably between sites dominated by sagebrush species. Mountain big sagebrush (*A. tridentata* subsp. *vaseyana*) is well adapted to fire and may recover in 15-20 years, but species occurring on more arid sites such as Wyoming big sagebrush (*A. tridentata* subsp. *wyomingensis*) may not fully recover in 50-75 years (Blaisdell et al. 1982; Bunting et al. 1987). The length of time that herbaceous production will be increased is therefore longer for Wyoming big sagebrush sites than for mountain big sagebrush sites. The amount of herbaceous production is lower on Wyoming big sagebrush sites, however.

Other reasons for using prescribed fire in the pinyon-juniper and sagebrush-grassland types are 1) to increase forb productivity (Harniss and Murray 1973); 2) to increase habitat diversity (Lyon et al. 1978); 3) to control invasion of other conifers such as Douglas-fir (*Pseudotsuga menziesii*) (Gruell et al. 1986); 4) to alter herbivore distribution (Klebenow and Beall 1977); 5) to enhance forage palatability and nutritive quality (Hobbs and Spowart 1984); and 6) to prepare sites for reseeding (Monsen and McArthur 1985).

INTERACTION OF FIRE AND OTHER ENVIRONMENTAL FACTORS IN DETERMINING EFFECTS ON PLANT COMMUNITIES

Prescribed burning can be an ecologically and economically sound method of managing sagebrush-grass and pinyon-juniper vegetation; however, there are many limitations to the use of fire in these communities. Herbaceous productivity is inherently low in many communities and is reduced further by the increase of sagebrush, juniper, and pine. Sites with less than 600 kg/ha of fine fuels will be difficult to burn. Sagebrush may compensate for low fine fuels to some degree (Bunting et al. 1987), but burns will still have to be conducted on sites with greater than 20% canopy coverage of sagebrush and 300 kg/ha of fine fuels in order to sustain the fire. Many sites produce less fine fuel, precluding prescribed fires. The fine fuel load situation is often more critical in many pinyon-juniper woodlands. Although sufficient fuel loads are needed to sustain a fire, the fire must burn with an intensity adequate to scorch the trees. Many pinyon-juniper and juniper woodlands have advanced to a stage of succession where prescribed fire is no longer a viable management alternative. Low fuel loads may be further reduced by poor growing conditions during the summer prior to the fire. This possibility must always be considered when planning prescribed fires in these types, and contingencies should be planned in its event. Even if sites with low amounts of herbaceous plant coverage are burned, the post-fire response of the community is often unsatisfactory. It may take many years for the desirable perennials to become established, which leaves the site open and susceptible to soil erosion or weed invasion.

As previously discussed, the understory in many sagebrush-grass and pinyon-juniper sites is dominated by annuals. The fuel load may be sufficient to sustain a fire, but the presence of annuals may prevent the establishment of perennial species. Annuals often increase following the fire, creating a greater fire hazard. This may then initiate conditions where wildfires are more likely to reburn the site in future years. Frequent fires will prevent the reestablishment of shrubs and may reduce the existing perennial herb populations. Competition from annual plants may also prevent the establishment of perennial plants. The only way to break this cycle is to increase the FFI to levels where the perennial vegetation can become established.

Fire has been used to reduce annual populations prior to seeding rangelands. This has usually met with limited success. Adequate seed reserves remain viable in the soil to replenish the annual plant's density within 1 or 2 years following the fire. The period of annual reduction is not usually long enough to allow for the establishment of the perennial seedling. Fire can be used as a pretreatment to seeding in sagebrush communities depleted of perennial herbs if levels of annual grasses are low at the time of the fire. In these situations, perennial seedlings can become established before the annuals dominate the site if they are seeded the first year following the fire.

Species diversity will usually increase but it is necessary to know the potential of the community involved. Wyoming big sagebrush communities, for example, have a low forb content in all successional stages and do not increase greatly in diversity when compared to other sagebrush types. In other situations, the forb component may be depleted by past use, and more time will be required to achieve the same results as in a community where a rich forb component exists prior to the fire.

The optimum amount of rest and deferment that is needed following fire in sagebrush-grass and pinyon-juniper vegetation continues to be a controversy. The amount of nonuse necessary after fire varies considerably with vegetal composition, site potential, objectives of the burn, and environmental conditions following the fire. This variation contributes to the controversy. The postfire grazing must be planned well in advance, and the manager must be ready to accommodate the concentrated herbivore use that will result from increased forage palatability on the burned site.

The size of the burn unit and the percentage of the unit to be burned is often a controversial point when planning prescribed fires. For many objectives several small burns (<20 ha) are most desirable to increase diversity and permit the best utilization of the burned areas; however, small burns may be easily overgrazed by large herbivores, which are attracted to the more palatable forage. This problem may be reduced by burning many small units within an area. Economics is also a factor in determining size of prescribed fires. The costliest portion of conducting a prescribed fire is establishing and burning out fire lines. The smaller the size, the greater will be the perimeter per unit area. The cost per unit area usually declines as the size of the burn unit increases, up to some point. The costs per unit area then stabilize or may even increase as the fire becomes more complex. In sagebrush-grasslands and pinyon-juniper woodland vegetation the optimum size is often between 200 and 1000 ha when hand-firing techniques are used. If aerial ignition is used the optimum area may be substantially larger (Bunting et al. 1987). Smaller burned areas can sometimes be accomplished on large burn units by igniting the fire under conditions of lower temperatures and higher fuel moisture than normal. This often leaves greater amounts of the unit unburned. This is more practical when fuel loading is irregular than when burning in heavy continuous fuels.

CONCLUDING REMARKS

In summary, prescribed fire can be an economic and ecologically sound method for meeting a variety of land management objectives in sagebrush-grassland and pinyon-juniper woodland vegetation. There exist situations in which fire may not produce the desired results, however. Low fine fuel loading is a common problem. Fire does not result in substantial increases of herbaceous perennial plant populations on sites dominated by exotic annuals. Concentrated large herbivore use should be expected and included in the planning process. If guidelines are carefully followed, however, vegetation can be successfully managed with prescribed fire.

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EFFECTS OF PRESCRIBED FIRE UPON WILDLIFE HABITAT IN NORTHERN MIXED-GRASS PRAIRIE

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ABSTRACT

Fire effects on wildlife and wildlife habitat in northern mixed-grass prairie ecosystems may be positive or negative depending on the uniformity, intensity, duration, frequency, location, shape, size, and timing of the fire and 1) the stage in the life cycle of the species involved; 2) the size of the home range of the species involved; and 3) habitat needs of the species involved. Wildlife is a product of the habitat, which is often the product of fire. Native wildlife and their habitats are, therefore, generally well-adapted to fire in their environment.

INTRODUCTION

The use of fire to manage habitats has been inconsistent in the northern mixed-grass prairie ecosystem of the north-central United States and south-central Canada. Inconsistent fire use has occurred because of three primary changes in demographics and life subsistence activities: 1) the reduction of Native American use of fire after 1875, 2) fire suppression and land-use changes that put increasingly more acreage under annual tillage, and 3) philosophical attitudes against the use of fire due to the media's overemphasis of the harmful effects of fire as commonly seen in "Bambi" and "Smokey the Bear" educational and entertainment materials between approximately 1940 and the present (Higgins et al. 1989a).

We believe that one of the main reasons that people have been reluctant to initiate the use of fire in resource management programs in the northern mixed-grass prairie is the lack of knowledge about the effects of fire on the plants and animals in the region.

Our primary objective is to provide information concerning fire effects on northern mixed-grass prairie with an emphasis on wildlife management. In several instances we draw from published literature outside the geographic region to provide a more complete reference for readers and decision makers.

The northern mixed-grass prairie is located in eastern Montana, eastern Wyoming, all but the eastern edges of North and South Dakota, southeastern Alberta, and southern Saskatchewan (Wright and Bailey 1980). Annual precipitation varies from 38 to 48 cm/yr in mesic areas to <38 cm in semiarid regions.

EFFECTS OF FIRE ON UPLAND GRASSES AND FORBS

The effects of fire on most plant species in northern mixed-grass prairie are not well known, particularly effects associated with long-term burning. Most of the available information has been based on short-term post-fire evaluations (Dix 1960; Kirsch and Kruse 1973; Schripsema 1977; Wright and Bailey 1980).

Fire was an important natural component of many grassland communities (Daubenmire 1968). Although historical records of fire in the Great Plains are limited (Higgins 1984), fire suppression since the early 1900s has changed the structure and composition of many plant communities, particularly those communities subject to frequent fires (Daubenmire 1968; Wells 1970; Bailey and Wroe 1974; Gartner and White 1986; Gartner et al. 1986).

Because of the complexity of factors and the lack of data concerning burns in the same community under similar circumstances, the effects of fire are often confusing and misleading. The proper time to burn can be based on physiological stages (e.g., growth stages where buds are exposed).

Species of cool-season and warm-season plants growing in proximity may respond differently to the same fire. Seasonal timing is a critical variable that affects the impact of fire on grasslands (Bragg 1982; Wright and Bailey 1982). Those species actively growing when an area is burned are much more susceptible to injury and death than dormant species or those just initiating growth (Anderson et al. 1970). Spring and fall fires occur when many cool-season plants are actively growing but when most warm-season plants are either dormant or have not yet expended a significant amount of stored energy on new growth. Summer fires often occur when cool-season plants have nearly stopped growing or are dormant. Fire at this time is usually detrimental to warm-season species (Vogl 1974).

The ability of prescribed fires to selectively suppress or promote a particular species depends primarily upon the date of the fire in relation to the phenology of the particular species.

Species competition can be reduced by spring burning. Repeated burning on the first of March resulted in a sharp decrease in the number of Kentucky bluegrass (*Poa pratensis*) plants (Ehrenreich 1959; Bailey 1978; Engle and Bultsma 1984). Most native grasses are still dormant at the time that Kentucky bluegrass has begun to grow and is highly susceptible to heat injury from fire. Thus, warm-season native grasses have higher yields because of decreased competition from cool-season invaders such as Kentucky bluegrass. A sequence of fires is usually necessary to restore grasslands back to proper condition.

Although there are many environmental factors that alter the effects of burning on vegetation, drought is the most limiting to grass production in the northern mixed-grass prairie (Hopkins et al. 1948; Wright and Bailey 1980; White and Currie 1983; Engle and Bultsma 1984). In the more arid regions of the northern mixed-grass prairie, fire can result in decreased herbage yield (Gartner et al. 1978) and critical reductions in litter (Dix 1960). The effects, however, differ primarily with the season of burning, pre- and post-burn precipitation, and plant species (Clark et al. 1943; Coupland 1973).

Fire severity, which is closely related to fuel amounts and distribution, weather, and moisture content of soil and fuel, is also a major factor affecting fire damage to plants (Wright and Bailey 1982).

Effects of fire on native grasslands are varied, but evidence shows prairie that is neither grazed or burned soon begins to deteriorate in quality (Anderson et al. 1970; Kirsch and Kruse 1973; Schacht and Stubbendieck 1985).

In summary, some general statements can be made regarding production from grasses in the northern mixed-grass prairie following fire. Big bluestem (*Andropogon gerardi*) increased in herbage during all periods of spring burning. Little bluestem (*Schizachyrium scoparium*) was also productive under burning but not to the degree of big bluestem. Although sideoats grama (*Bouteloua curtipendula*) yields remained constant, blue grama (*B. gracilis*) yields increased after spring burning. Responses of *Stipa* species varied with spring burning. Prescribed burning is a viable management technique to manage grasses in the northern mixed-grass prairie ecosystem.

EFFECTS OF FIRE ON SHRUBS AND TREES

Fire is commonly used in rangelands to remove shrubs of low foragevalue and excessive herbaceous litter (Stoddart et al. 1975). Burning increases range browse availability mainly by reducing shrub crown heights, adding new browse plants through seed germination, and increasing palatability associated with new young growth (Vallentine 1971; Mathews 1984).

After fall burning there is no regrowth of winter browse for wildlife. After spring burns, shrubs usually take from 4 to 8 weeks to sprout with no major reduction in winter browse. Spring burns usually increase sprouting, but fall burns promote a taller regrowth the following year. After both spring and fall burns, shrubs are reduced in height and twig diameter, making regrowth more available for animal use (Leege and Hickey 1971). Fires affect shrubs in relation to plant age, soil moisture at time of burn, intensity of fire, season of burn, health of plants, and frequency of droughts. To maintain a healthy plant community, it is best to burn when the plants you wish to preserve are dormant and soil moisture is good (Wright 1972). The season and frequency of fire can determine the net change, if any, in the density of sprouting species. If fire occurs before active growth has begun, an increased density from sucker development may result (Anderson and Bailey 1980). When a plant is actively growing and translocation of nutrients has occurred, fire can be detrimental or lethal to the species (Smith and Owensby 1973).

On rough fescue (*Festuca scabrella*) prairie, brush up to 2.5 cm in diameter at flame height was top-killed by backing fires, whereas most brush up to 5 cm in diameter was top-killed by headfires (Wright and Bailey 1982). In all cases, fuel loads and moisture, topography, and weather may influence the degree of top kill of deciduous species. Shrub densities were not reduced 1 and 2 years after a wildfire burned through a deciduous woodland in southwestern North Dakota, and the fire stimulated vigorous sprouting of many shrub species (Zimmerman 1981).

EFFECTS OF FIRE ON EMERGENT VEGETATION IN PRAIRIE WETLANDS

Wetlands often become choked with emergent vegetation and are in need of manipulation to increase the ratio of open water to cover (Linde 1969). Fire can be used to open up dense stands of vegetation in marshes (Ward 1942; Uhler 1944; Schlichtemeier 1967; Ward 1968; van der Toorn and Mook 1982; Ball 1984). Burning has also been used to control plant succession to promote the aquatic plants that produce seeds and roots for waterfowl foods (Grange 1949; Yancey 1964), and to improve the use of wetlands by breeding waterfowl (Evans and Black 1956).

Common reed (*Phragmites australis*) can be maintained or increased using spring and fall burns, or reduced and eliminated using summer burns (Ward 1942). Fire in stands of phragmites with dry substrates in June through August combines the effect of burning when carbohydrate reserves are low with the potential of burning deep into organic soils. Such a burn could have a significant impact on the rhizome network of a dense stand of phragmites.

Cattail (*Typha* spp.) has become a problem in many prairie wetlands because it often forms dominant monotypic stands (Linde et al. 1976) that are less attractive to wildlife (Kantrud 1986). Fire is often used to increase open water interspersion in cattail stands (Uhler 1944; Beule 1979; Ball 1984).

A slow-moving fire that burns deep into the organic soil or peat of wetland substrates will have a negative impact on emergent hydrophytes (Uhler 1944; Yancey 1964; Millar 1969). Uhler (1944) noted that such a fire, called a "root burn," controlled phragmites, cordgrass (*Spartina* spp.), cattail, river bulrush (*Scirpus fluviatilis*), sedges, and other hydrophytes. The use of this kind of fire is limited to marshes in which the water can be completely drained or to those marshes experiencing severe drought.

Seasonal fire effects on 67 species of plants are shown in Table 1.

EFFECTS OF FIRE ON INSECTS

Timing is a major factor in insect fire ecology. Early spring burning results in earlier emergence and higher numbers of grasshoppers (*Acrididae*) than late-spring burning, especially if the early burn is coupled with heavy grazing by domestic livestock (Arnett 1960; Knutson and Campbell 1976). Areas burned in late March produced greater grasshopper populations than heavily grazed areas (Arnett 1960). Late-spring burning reduces insect populations more than early spring burning. The use of fire is an age-old method to control insects and diseases in crop residue. The effect of fire on grassland insect populations is not as well understood or documented. Insects, especially grasshoppers, are an important herbivorous component of grasslands. Fire causes an immediate decrease in insect populations (except ants [*Formicidae*] and other underground species) followed by a gradual increase in numbers as the vegetation recovers. Insects eventually reach a population higher than adjacent areas, then decline to near preburn levels as vegetation and soil litter stabilize or return to preburn amounts.

EFFECTS OF FIRE ON NONGAME BIRDS

Bird species evolving with fire may show fire-adapted behavior and responses, whereas other species exposed infrequently to fire in their evolutionary histories may be severely inhibited by it (Best 1979).

The immediate effect of fire on bird populations depends greatly upon the season and intensity of the

Table 1. Effect of fire on selected prairie plants (from Higgins et al. 1989b)

Species	Season of fire occurrence[a]		
	Spring	Summer	Fall
Big bluestem (*Andropogon gerardi*)	+		
Little bluestem (*Andropogon scoparius*)	+		
Indian grass (*Sorghastrum nutans*)	+		
Switch grass (*Panicum virgatum*)	+		
Sideoats grama (*Bouteloua curtipendula*)	o		
Blue grama (*Bouteloua gracilis*)	+		
Prairie dropseed (*Sporobolus heterolepis*)	+		
Canada wild rye (*Elymus canadensis*)	o		
Western wheat grass (*Agropyron smithii*)	+o-	+	+o-
Tall wheat grass (*Agropyron elongatum*)	+		
Intermediate wheat grass (*Agropyron intermedium*)	+		
Quack grass (*Agropyron repens*)	-		
June grass (*Koeleria pyramidata*)	+	-	
Needle and thread (*Stipa comata*)	-+		
Green needle grass (*Stipa viridula*)	-+		
Porcupine grass (*Stipa spartea*)	-+		
Spike oat grass (*Helictotrichon hookeri*)	+		
Canada bluegrass (*Poa compressa*)	-		
Kentucky bluegrass (*Poa pratensis*)	-+		
Smooth brome (*Bromus inermis*)	+		
Japanese brome (*Bromus japonicus*)	-	-	
Cheatgrass (*Bromus secalinus*)	+-	+-	+
Threadleaf sedge (*Carex filifolia*)	-		
Flodman's thistle (*Cirsium flodmanii*)	-o		
Wild blue indigo (*Baptisia australis*)	+		
White sage (*Artemisia ludoviciana*)	-o		
Fringed sage (*Artemisia frigida*)	-o		
Wormwood (*Artemisia absinthium*)	-o		
Western yarrow (*Achillea millefolium*)	-o		
Yellow coneflower (*Ratibida columnifera*)	-o		
Northern bedstraw (*Galium boreale*)	-o		
Western ragweed (*Ambrosia psilostachya*)	-o		
Stiff sunflower (*Helianthus rigidus*)	-o		
Maxmilian sunflower (*Helianthus maximilianii*)	+		
Silverleaf scurfpea (*Psoralea argophylla*)	+	+	
Pasque flower (*Anemone patens*)	+		
Many-flowered aster (*Aster falcatus*)	+		
Lady slipper (*Cypripedium* spp.)	+		
White camas (*Zigadenus elegans*)	+		
Tiger lily (*Lilium philadelphicum*)	+		
Tall gayfeather (*Liatris ligulistylis*)	+		
Sweet clover (*Melilotus* spp.)	+-	-	-
Purple prairieclover (*Dalea purpurea*)	+		
Harebell (*Campanula rotundifolia*)	+		
Alfalfa (*Medicago sativa*)	+	-	-
Leadplant (*Amorpha canescens*)	+		
Leafy spurge (*Euphorbia esula*)	+o-		

Continued on next page

Table 1 continued

Species	Season of fire occurrence[a]		
	Spring	Summer	Fall
Serviceberry (*Amelanchier alnifolia*)	+-	-	
Arkansas rose (*Rosa arkansana*)	+o	+	
Wood's rose (*Rosa woodsii*)	+o	+	
Raspberry (*Rubus* spp.)	+-	+	
Choke cherry (*Prunus virginiana*)	+		
Ribes (*Ribes* spp.)	-	-	
Smooth sumac (*Rhus glabra*)	+		
Posion ivy (*Rhus toxicodendron*)	+o	+	
Silverberry (*Shepherdia argentea*)	-	-	
Silver sage (*Artemisia cana*)	-o+	-	
Western snowberry (*Symphoricarpos occidentalis*)	+-	-+	+-
Buckbrush (*Symphoricarpos orbiculatus*)	+o-		
Gray rabbit brush (*Chrysothamus nauseosus*)	-		
Broom snakeweed (*Gutierrezia sarothrae*)	-+		
Hawthorn (*Crataegus* spp.)			
Rocky Mountain juniper (*Juniperus scopulorum*)	-		
Phragmites (*Phragmites australis*)	+	-	+
Whitetop (*Scholochloa festucacea*)	+o	+	
Cattail (*Typha* spp.)	-	+	
Bulrush (*Scirpus* spp.)	o		

[a] + = Increased; o = No change; - = Decreased. Multiple symbols indicate variable fire effects for that season as indicated in the literature.

burn. A relatively cool fire during the dormant season could greatly increase food sources (Wright and Bailey 1982). Birds are adapted to eat particular kinds of food such as seeds and insects, and the birds' abundance may depend largely on the supply of the appropriate kind of food (Bendell 1974).

Fire temporarily reduces breeding pair density, alters nest site selection, and changes foraging behavior, at least during the first breeding season after burn. The duration of the impact depends on the extent of the habitat alteration. Two or three breeding seasons were required to increase bird species numbers to preburn densities (Forde et al. 1984).

The frequency of fire may render a habitat unsuitable for a given species, depending on its habitat requirements. When prescribed burning creates and maintains a fine-grained mosaic with good interspersion of habitat types, the greatest number of species requiring subclimax vegetation will benefit (Best 1979; Winter 1984).

FIRE EFFECTS ON UPLAND GAME BIRDS

Recently burned areas appear to be attractive sites to greater prairie-chickens (*Tympanuchus cupido*) and sharp-tailed grouse (*T. phasianellus*) (Kirsch and Kruse 1973; Sexton and Gillespie 1979). These species also appear to increase in density in burned versus unburned areas. Mourning doves (*Zenaida macroura*) have not exhibited significant population changes in response to burning; however, they have exhibited a change in nesting habitat selection, from trees and shrubs in unburned areas to ground cover in burned areas (Soutiere and Bolen 1973).

The responses of ring-necked pheasants (*Phasianus colchicus*) and gray partridges (*Perdix perdix*) to grassland fires have not been researched sufficiently to draw any specific conclusions. One would expect, however, that species that have evolved within the grassland environment would also have become more fire tolerant and perhaps more fire dependent than those that have not.

There is no information that relates fire effects to the life cycles of upland game. Those studies conducted have not been replicated, limiting interpretation between populations. Although complete information on fire and upland game bird relationships is lacking, in general, enough basic information exists to use fire as an effective management tool (Kirsch and Kruse 1973).

EFFECTS OF FIRE ON WATERFOWL

Only in very recent times have scientific studies been conducted to determine if burning, both natural and prescribed, is harmful or beneficial to waterfowl.

Most information available on the response of waterfowl to burning concerns spring burns. The obvious immediate effect of spring fires on upland nesting waterfowl is destruction of nests and their contents by fire (Leedy 1950; Moyle 1964; Erwin and Stasiak 1979). In North Dakota prairie burns there are sometimes "skips" or areas that remain unburned, and active nests in these areas are not affected by the fire (Kruse and Piehl 1986). Burning during the nesting season does not necessarily eliminate all ground nesting in an area for that year.

Kirsch and Kruse (1973) compared nesting on similar plots of unburned and burned prairie for several years following spring burning. They found that 52% of the duck nests on burned grassland habitat were successful compared to 33% on unburned areas. During the second season after the fire, duck production was greater on the burned plot than on the unburned plot. The greatest measured change in vegetation after burning is a marked increase in plant variety. Burning also changed the growth form and pattern of nesting cover, which may make it more attractive to nesting waterfowl.

A major concern with spring burning is the destruction of active nests; this problem is avoided with fall burns. Higgins (1986) compared nesting success of waterfowl on mixed prairie areas burned in spring with those burned in fall in North Dakota. Duck nesting success was greater in the fall-burned plots than in spring-burned plots over a 3-year period. During the first spring after fall burns, little cover was available for nesting and the area was sparsely utilized. During the second year the available nesting cover on fall-burned plots was much taller and denser, and nesting success was higher. Upland waterfowl nesting success was nearly equal between the spring and fall burns after the third postfire growing season. Duck production can be greater on fall burns than on spring burns if averaged over 3 or 4 postburn years (Higgins 1986).

EFFECTS OF FIRE ON SHOREBIRDS

Some research has evaluated the effect of fire on shorebird nesting habitat. In Minnesota, killdeer (*Charadrius vociferus*) were attracted to recently burned shorelines (Niemi 1978).

More upland sandpiper (*Bartramia longicauda*) broods were produced on burned grasslands than on unburned or grazed areas (Kirsch and Kruse 1973). Kirsch and Higgins (1976) reported that prairie burned twice over a 5-year period had higher production of upland sandpipers than idle or grazed prairie. They suggested burning at 3-year intervals. Upland sandpipers made greater use of native prairie burned in early May, compared to grazed prairie; in June 50 upland sandpipers were in the burned prairie and none were in the grazed (Huber and Steuter 1984). In July the burned area had 24 sandpipers compared to 6 sandpipers on the grazed area.

EFFECTS OF FIRE ON SMALL MAMMALS

Research indicates limited direct mortality to rodents, but several instances have been reported. An immediate, indirect cause of mortality due to burning is predation. The lack of cover immediately after a fire produces an exposed environment and improves accessibility to avian and mammalian predators (Motobu 1978). Some of the mortality associated with fire may have actually been caused by predation (Beck and Vogl 1972).

Fires affect population densities principally by altering habitat. The decrease of vegetative cover and litter results in fewer microhabitats available for use by rodents. With the reduction of ground litter, however, primary production is enhanced, and within 2-4 years following a fire, a gradual accumulation of litter and a decrease in primary production occur (Dix 1960; Vogl 1965; McGee 1982). Based upon these habitat changes and the habitat and food preferences of rodents, major shifts in species composition and density should also occur within the first few years after a fire.

The major changes that occur in food availability affect the type of species that will invade after a fire.

Removal of the litter layer increases availability of seeds and invertebrates for use by granivores and omnivores (Ahlgren 1966; Stout et al. 1971; Kaufman et al. 1983). For the first year, these types of rodents are abundant. Herbivores are limited, especially on complete burns. As the abundance of seeds decreases, so does the population of granivores; however, by the third year new seed-producing vegetation has become established and the seed-eating rodent populations increase (Ahlgren 1966; Sims and Buckner 1973). Concealment vegetation develops after 2-5 years, depending upon climatic conditions. This increased vegetation allows herbivores and those rodents restricted by lack of cover to recolonize an area and reach populations similar to preburn levels (Gashwiler 1970; Fala 1975; McGee 1976).

The small-mammal response is not considered a direct response to fire but rather a reaction to fire-altered habitat. Fire alters the composition of rodent species from those associated with the climax community to those considered early successional species (McGee 1982). Food and habitat resources are the primary factors influencing the population shifts and fluctuations. Granivores and omnivores that require little cover such as deer mice (*Peromyscus maniculatus*) are favored. As vegetative cover increases on burned areas, other rodent species such as voles (*Microtus* spp.) become dominant. Eventually, litter accumulation, flora, and the rodent community again resemble that of an unburned area.

EFFECTS OF FIRE ON LARGE MAMMALS

Fire is a major influence on the structure of a grassland ecosystem. Fire and fire-perpetuated environments such as grasslands have been of the utmost importance in the evolution of mammals and directly or indirectly affect the lives of many mammal species today (Handley 1969).

Fire suppression in the Black Hills of South Dakota resulted in thickening of pine stands and decreases in secondary stages of plant succession important to mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) (Loovas 1976). Small burns of variable intensity can improve deer habitat by creating temporary openings, improving shrub growth, and generally creating more diversity by changing the age class structure of vegetation (Wallmo 1981). Bison (*Bison bison*) in Wind Cave National Park, South Dakota, showed a strong affinity for prescribed burn areas (Forde et al. 1984).

Fire lowers animal populations principally by altering habitat, not by killing animals. The greatest number of deer will be produced by maintaining the habitat in the early stages of plant succession by methods that include burning (Troester 1970). A patchy burn with about 20% unburned vegetation is most desirable for most wildlife species (Wright 1974). This condition leaves adequate cover and winter food for big game.

The increased nutritional quality of burned grasslands provides good summer range capable of carrying deer in good condition through the breeding season, a necessary requirement for maximum herd productivity. White-tailed deer on poor rangeland showed lower ovulation rates than those on good rangeland (Julander et al. 1961).

No white-tailed deer fawns occurred on an unburned 50-ha plot compared to four fawns each during the second growing season on burned plots of 55 ha and 49 ha on the Woodworth Study Area, North Dakota (Kirsch and Kruse 1973).

Controlled burning of aspen provides more browse for deer. Following a spring burn, aspen stem densities increased from a few hundred before the fire to greater than 10 000/ha because of root sprouting (Gordon 1976). Before treatment, aspen browse was too tall for ungulates to reach. Two years after the burn a large supply of aspen was at a height that could be used. These burns appeared to inexpensively provide not only an increased food supply but increased cover.

Immediate and long-term fire effects on 28 species or groups of wildlife are shown in Table 2.

SUMMARY

Because of the frequency of historical fires in the northern mixed-grass prairie (Higgins 1984) and the apparent adaptability of many native plant species to fire, it is likely that fire was originally an important force affecting productive plant communities in this ecosystem.

The use of prescribed burning is a valuable management tool for upland nesting birds in grassland areas. The optimum timing and frequency of prescribed burns is still being researched. Controlled burning is an efficient tool in wildlife management, but indiscriminant annual burning reduced the quality and quantity of waterfowl nesting cover (Fritzell

Table 2. Effect of fire on wildlife (from Higgins et al. 1989b)

Species	Effects[a] Immediate	Long-term
Grasshopper sparrow (*Ammodramus savannarum*)	-	
Le Conte's sparrow (*Ammodramus leconteii*)	-	+
Vesper sparrow (*Pooecetes gramineus*)	+-	+
Savannah sparrow (*Passerculus sandwichersis*)	-	+
Field sparrow (*Spizella pusilla*)	-	+
Chipping sparrow (*Spizella passerina*)	+	
Lark sparrow (*Chondestes grammacus*)	o	-
Western meadowlark (*Sturnella neglecta*)	+	
Bobolink (*Dolichonyx oryzivorus*)	-	+
Gray catbird (*Dumetella carolinensis*)	+	
Killdeer (*Charadrius vociferus*)	+	o
Upland sandpiper (*Bartramia longicauda*)	+	+
Mourning dove (*Zenaida macroura*)	o	o
Greater prairie chicken (*Tympanuchus cupido*)	+	+
Sharp-tailed grouse (*Tympanuchus phasianellus*)-	o	
Ring-necked pheasant (*Phasianus colchicus*)	-	o
Gray partridge (*Perdix perdix*)	-	o
Ducks (*Anas* spp.)	-	+
Western harvest mouse (*Reithrodontomys megalotis*)-	o	
Deer mouse (*Peromyscus maniculatus*)	+	o
Voles (*Microtus* spp.)	-	o
Jumping mice (*Zapus* spp.)	-	o
White-tailed deer (*Odocoileus virginianus*)	+-	+
Mule deer (*Odocoileus hemionus*)	+-	+
Bison (*Bison bison*)	+	+
Elk (*Cervus elaphus*)	+-	+
Pronghorn (*Antilocapra americana*)	+	

[a] Immediate = < 1 year after fire; long-term = > 1 year after fire; + = Increased; o = No change; - = Decreased. Multiple symbols indicate variable fire effects for that season as indicated in the literature.

1975). Native grasslands should be burned 2 out of 5 years (Kirsch and Higgins 1976). Land managers who burn in the spring should consider partial burns if they are concerned about nesting birds (Kruse and Piehl 1986). Partial burns have less impact on total vegetation changes but can result in higher recruitment rates than complete burns. Annual fall burning would be harmful to wildlife because of the lack of residual nesting cover, and it is suggested that to enhance waterfowl production burning should be conducted every other year at most (Higgins 1986).

Fire creates vegetative diversity and therefore enhances wildlife habitat. Optimum benefits occur where fire creates a mosaic pattern of burned and unburned vegetation that provides new growth of nutritional forages, seasonal habitats, and maintenance of vegetation in early stages of succession.

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FIELD TRIP NOTES
VEGETATION AND FIRE MANAGEMENT IN BANFF NATIONAL PARK, ALBERTA

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INTRODUCTION

Canadian Parks Service policy requires that "natural resources will be protected and managed with minimal interference to natural processes to ensure the perpetuation of naturally evolving land and water environments and their associated species." This mandate provides an extreme challenge to the managers of Banff National Park (BNP); not only does the park have a natural resource base largely dependent on processes such as fire, forest insects and disease, and winter snow avalanches, but it also has very high visitation (greater than 7 million people per year) and several billion dollars worth of visitor facilities. Furthermore, BNP straddles the Trans-Canada Highway and the Canadian Pacific Railway for nearly 100 km. Both are critical national transportation links that must be kept open at all times.

PROPOSED PARK ZONES

The emerging strategy for managing BNP vegetation is based on delineating the park into the following four zones.

Minimal Human Intervention Zone

In this zone there would be maintenance of benchmark vegetation communities with minimal management. This features a lightning fire regime only, forest insect and disease agents functioning with minimal control, and no facility development requiring widespread mechanical manipulation (e.g., powerlines). This zone is proposed for the northern, less-developed areas of Banff National Park.

Natural Process Zone

In this zone there would be maintenance of long-term environmental processes to which native plant communities are best adapted. Features include re-establishment of pre-European fire regime (this included aboriginal fires) through the use of planned- and random-ignition prescribed fires, forest insects and diseases functioning with minimal control, and no facility development requiring widespread mechanical manipulation. This zone is proposed for much of the lower Bow Valley and southern half of the park.

Intensive Management Zone

In this zone, aesthetically pleasing and relatively naturally appearing vegetation would be maintained by mechanical manipulation. This emphasizes protection of public safety and facilities through selective tree removal to enhance forest vigor, reduce fuels, and minimize insect and disease impacts. This zone is proposed for limited areas around the Banff and Lake Louise townsites, ski areas, and park boundary areas.

Selective Exclusion of Natural Processes Zone

In this zone, maintenance of steadily aging forest vegetation features suppression of man-caused and lightning-ignited fires, minimal mechanical intervention, and generally no control of forest insect and disease agents. This is a default zone that would be applied where other options are limited due to costs or other constraints.

This zoning scheme reflects an adaptive management strategy that acknowledges that vegetation management is a developing art and science. Park staff will have to learn as they go and recognize that there is no single correct way to manage vegetation.

THE LOWER BOW VEGETATION MANAGEMENT UNIT

The Lower Bow Vegetation Management Unit (VMU) in Banff National Park consists mainly of warm and dry montane forests dominated by Douglas-fir, lodgepole pine, white spruce, and trembling aspen. Fire history studies indicate pre-European fire cycles of less than 50 years. Low-intensity fires were common, resulting in multi-aged forests. Fires have been more or less excluded from the unit since 1910. The unit has the highest proportion of ungulate winter range in the park and also the greatest concentration of park facilities.

The Lower Bow VMU is largely zoned for either natural process maintenance or intensive management. To maintain natural processes, Banff National Park has established 67 planned-ignition prescribed fire units in the Lower Bow VMU. In the future, units may be selected randomly for burning based on predetermined fire cycles. This procedure would closely duplicate the natural fire process. For example, a unit assigned with a 40-year cycle would be evaluated annually with a 1 in 40 probability of burning. Currently, however, managers choose units subjectively to gradually build up their experience base.

Since 1983, park staff have burned five units totaling about 2000 ha. Fire behavior has ranged from creeping surface fires with flame lengths of less than 1 m to expansive crown fire runs with convection columns rising several thousand metres about the mountain peaks. Staff have recorded information on all prescribed fires including pre- and post-burn fuels, vegetation and wildlife use, Canadian Forest Fire Danger Rating System indexes, fire weather conditions, and fire behavior and impact characteristics.

The experience gained from the program to date has been immense, and accomplishments include the following:

- evaluation of public reaction to prescribed burns seen by millions of people in a high profile location;
- construction of low-impact fire lines designed to contain crown fire;
- evaluation of cost-effective and safe firing techniques including the use of aerial (e.g., flying drip torch) and hand-held ignition devices;
- observation of mountain fire behavior under a diverse range of weather, fuel, and topographic conditions;
- analysis of vegetation and wildlife response to fires of various intensities and in various seasons;
- mobilization of fire command teams and fire crews from across the country to participate in the execution of the prescribed fires; and
- excellent cooperation from other agencies (e.g., Alberta Forest Service, B.C. Forest Service, Forestry Canada, Atmospheric Environment Service) in the form of fire weather forecasts, prescribed fire advisors, prescribed burning prescriptions, fire crews, and helicopter support.

The Banff National Park prescribed fire management program is in most respects a success. Operational prescribed fire costs have been reduced to less than $20/ha, and fire escapes have been few. Preliminary indications are that the vegetation management program will, as intended, "ensure the perpetuation of naturally evolving land and water environments and their associated species."

THE AUTHOR

CLIFF WHITE is the National Fire Management Coordinator for the Canadian Parks Service (CPS), headquartered in Ottawa, Ontario. He received a B.Sc. degree in forestry from the University of Montana (1977) and an M.Sc. degree in forestry from Colorado State University (1985). Cliff has worked for the CPS since 1973 in various positions including fire crew member, backcountry park warden, public safety warden, and from 1980 to 1987, vegetation and fire management warden in Banff National Park. Responsibilities in his present position with the CPS Natural Resources Branch focus on national implementation of CPS's fire management policy.

ALBERTA FOREST SERVICE HOSTED BANQUET

1988 INTERIOR WEST FIRE COUNCIL AWARD FOR OUTSTANDING CONTRIBUTIONS TO FIRE MANAGEMENT

Presentation by

Carson S. McDonald
Pine Ridge Forest Nursery
Alberta Forest Service
Smoky Lake, Alberta

Mr. Chairman, honored guests, ladies and gentlemen. Tonight, it's my distinct privilege to take part in recognizing the significant contributions of Charles F. (Frank) Platt to fire management in Canada, and more particularly the province of Alberta.

Frank Platt was born in England on March 14, 1915, and emigrated to Canada as a lad of 15 years old. Frank served his country in World War II from January 1940 to November 1945. His lengthy tour of duty included 4 years in England and 1 year on the continent of Europe. After "mustering out" in late 1945, Frank obtained employment in the spring of 1946 as a forest ranger-game officer with the Alberta Department of Lands and Forests. He rose rapidly in the ranks and in July 1953, was promoted to the position of Assistant Superintendent with the Forest Protection Branch of the Alberta Forest Service. There he found a vocation and a calling that he pursued for the rest of his professional career, until his retirement in December of 1974.

Mr. Platt's contributions to fire management, provincially and nationally, date back to 1953, when after a disastrous fire year he and several other key staff members were challenged with the task of upgrading and improving forest-fire protection capability in Alberta.

To quote Dr. Peter Murphy, Associate Dean of Forestry, Faculty of Agriculture and Forestry at the University of Alberta, "Frank Platt was both a visionary and a pragmatist with the remarkable capability of marring the two together. He saw problem(s) in broad terms, and approached their solution in a coordinated way." Several notable examples support Dean Murphy's statement:

- Commencing in 1954, Frank was charged with the responsibility of upgrading the fixed detection system throughout the province. As part of this activity and acting on an idea from Reg Loomis (past Director of Timber Management Branch of the Alberta Forest Service), topographic interpretation from aerial photography was utilized to locate and evaluate possible fire tower sites. Additionally, he was instrumental in the utilization of fiberglass-reinforced plastic for the construction of lookout cupolas and strongly supported the tying-in of the fixed detection to an overall communications network.
- In 1957, Platt initiated experiments with the aerial dropping of supplies to fire crews utilizing a Stinson-Voyageur and during 1958 was a driving force behind the province's purchase of its fixed-wing aircraft—a Fleet Courier and the lease of a Bell 47J helicopter. He personally evaluated the "smoke-jumper" program (1958) in Montana and recommended against adopting the concept. Instead, the logistical strategy of utilizing fixed-wing and helicopter combination(s) was implemented to get men and supplies to fires. Supporting this strategy, a centralized aircraft dispatch system was put in place, and a network of fuel caches and airstrips were eventually constructed over much of the Green Area of the province.
- Throughout his career, Mr. Platt was a strong advocate of training and organization in the fire suppression business. As early as 1956, mainly through his efforts and encouragement, a 3-day course for tower men was added to the curricula at Kananaskis. During the 1960s, fire crew training and organization was strongly enhanced, and following the disastrous fires of 1968, Alberta's fireline organization was completely overhauled, and staff were trained and certified for the various supervisory positions. The fire control training capability at the Forest Technology School in Hinton was significantly increased with the addition of more instructors, sponsoring of numerous specialized training courses, employment of new technology such as the fire simulator, and the use of outside expertise, etc.

- Frank's first love was probably equipment. Whenever possible he saw to the supply of first-rate fire equipment and missed no opportunity to upgrade the quality and quantity. Standardization was a watchword, and this approach was stressed provincially and nationally. If the equipment for a special purpose was not available commercially, he saw to its development, and he personally had a hand in the establishment of an equipment development section within the Alberta Forest Service.
- If fire equipment standards were a "watchword" with Frank, then rapid initial suppression was a religion. From the formation and utilization of four 4-man initial crews in 1955, through the development and use of helicopters in the late 1950s and air tankers during the 1960s and early 1970s, he never lost sight of this objective and moved to strengthen its capability at every opportunity.
- Nationally, Frank Platt mirrored many of his own efforts in Alberta and always stood four-square behind important concerns such as equipment standardization, equipment exchange, national fireline organizational structure(s), national training, etc.

In closing, I'm sure that if you speak to any of Frank's confreres, they would mention his commitment, his knowledge, his thirst to make improvements, his vision, and his propensity to speak his mind. He was and is respected in his profession. Mr. and Mrs. Platt, please come forward and be recognized for these contributions, and accept our appreciation.

THE AUTHOR

CARSON McDONALD is the Superintendent of the Alberta Forest Service's (AFS) Pine Ridge Forest Nursery at Smoky Lake, Alberta. He received his B.Sc. degree in forestry from the University of Montana (1963). Carson has worked for the AFS as Assistant Forester in the Slave Lake and Peace River forests (1964); Forester (timber management and silviculture), Lac La Biche Forest (1965-69); Headquarters Section Head (Operations), Forest Protection Branch (1968-75); Headquarters Section Head (Air Administration); Forest Protection Branch (1976-77); and Forest Superintendent, Slave Lake Forest (1978-86) prior to assuming his present position.

History of the Interior West Fire Council Award for Outstanding Ccontributions to Fire Management[1]

The idea of recognizing deserving individuals who have made outstanding contributions in the field of fire management is one of the traditions adopted from the Rocky Mountain Fire Council. An awards committee was established in 1975. The awards have been nonmonetary, although a cash award could have been included as well as a plaque at the discretion of the council membership. Awards were not made annually and on one occasion, two persons were honored. Between 1979 and 1987 eight awards were presented to:

- Bill Plourde (U.S. Forest Service), at Witchita, Kansas, in 1979, posthumously for his work with state foresters in the Rocky Mountain Region (R-2) of the U.S. Forest Service.
- Joe Range (Nebraska State Forest Service), a charter member of the Rocky Mountain Fire Council, at Cheyenne, Wyoming, in 1981, for his many years of dedicated service in fire management.
- Bert Miller (Simms Fiberglass) and Dean Shilts (U.S. National Park Service), at Rapid City, South Dakota, in 1983, both for their service in fire management and dedication to the Rocky Mountain Fire Council.
- Elmer Neufeld (Monsanto Inc.), at Lincoln, Nebraska, in 1984, for his long dedication and support to the Rocky Mountain Fire Council.
- Glen Rose (Bureau of Land Management), at Jackson, Wyoming, in 1985, for faithful support to the Rocky Mountain Fire Council.
- Randy Biswell (Kansas State and Extension Forestry), a charter member of the Rocky Mountain Fire Council, at Manhattan, Kansas, in 1986, for his long and dedicated service since the council's inception.
- Tim Murphy (Burlington Northern Railroad), at Jackson, Wyoming, in 1987, for his devotion and outstanding support to both the Rocky Mountain and Intermountain Fire councils.

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[1] Based on comments made by Ronald J. Zeleny at the Alberta Forest Service Hosted Banquet held during the first annual meeting and workshop of the Interior West Fire Council at Kananaskis, Alberta, on October 26, 1988.

ACCEPTANCE REMARKS

Charles Frank Platt
Alberta Forest Service (retired)
Devon, Alberta

Mr. Chairman, head table guests, ladies and gentlemen. I have no intention of wrecking this very fine meeting and delicious dinner by making a long speech. As I sat listening to the accolades from Carson McDonald I began to realize how dumb I had been in those days. I should have asked for a raise in wages long before I retired. The old cliché about a good woman behind every successful man crossed by mind, and as I sat looking at my wife I had some doubts. I don't think she was behind me—she was way ahead of me.

I feel very honored to receive this award from the Interior West Fire Council. Such an experience makes one humble. In addition to thanking you very much for this honor tonight, I would like to make a few unsolicited remarks which I will address in the main to our American cousins.

Last summer I grieved with you during your tragic fire problems south of here. I followed all the details as best I could through the press and could not help feeling sorrow at the terrible losses sustained during those fires.

Ladies and gentlemen, in my opinion the time has come to suppress all forest fires. You can delineate areas by different names and set various priorities on them, but a forest fire still remains a forest fire. I think it is obvious that the time has come to take a long hard look throughout North America, at prompt and total suppression of all "wildfire" in forested areas. To fail in this is like letting a genie out of the bottle. The big question then is, how and when do you put that genie back? I will listen with interest for the answer. Thank you.

INTERIOR WEST FIRE COUNCIL SCHOLARSHIPS

Presentations by

Jack W. Peters
Permanent Secretary-Treasurer,
Interior West Fire Council

I'm pleased to be able to present four deserving students with scholarships at this, the first annual meeting and workshop of the Interior West Fire Council (IWFC). These scholarships are in fact being presented as directed under the constitution and by-laws of the former Intermountain Fire Council (IFC) and will continue under the new constitution and by-laws of the IWFC. The monetary amounts associated with each of the scholarships are as follows:

- IWFC Scholarship—$U.S. 300.00
- Sandman IFC Memorial Scholarship—$U.S. 500.00
- Sandman Fire Scholarship—$U.S. 500.00

Two of the scholarships were established as a tribute to the memory of the late Richard J. Sandman ("Mr. Intermountain Fire Council"), formerly permanent secretary-treasurer of the IFC, who passed away in 1985. This year there are two co-recipients of the Sandman Fire Scholarship (i.e., each one receives $U.S. 250.00).

1988 Interior West Fire Council Scholarship
and
1988 Sandman IFC Memorial Scholarship

Introductions by:

Paul M. Woodard
Department of Forest Science
University of Alberta
Edmonton, Alberta

Alvin Kim Clark, recipient of the 1988 Interior West Fire Council Scholarship, is currently an undergraduate in the Department of Forest Science at the University of Alberta in Edmonton. Kim began his forestry career in 1972 as a summer student with the British Columbia Forest Service (BCFS). During the 1972 and 1973 fire seasons, Kim performed duties as lookout operator, tanker base worker, and served as straw boss on several fires. In 1974, Kim graduated from the British Columbia Institute of Technology with a 2-year technical diploma. In June 1974, he began working for the BCFS as an Assistant Ranger at Houston. Over the next 11 years, Kim gradually progressed to the position of Field Officer Supervisor. In 1985, he enrolled in the B.Sc. in forestry program at the University of Alberta, where he has maintained a 7.4 grade point average (9.0 scale; 6.0 is required for admission to graduate school), and has been actively involved in student activities. During the 1987-88 academic year, he was president of the Forest Society. From a forest protection perspective, Kim is certified by the BCFS as a Class B fire boss and a Class A line boss. He has served as the Lillooet District fire prevention and suppression coordinator. Kim served on a planning team that prescribed burned 8100 ha of standing timber in 1982-83 as part of a sheep habitat enhancement project. He has also worked on many fire protection plans for the various districts he has worked in and has coordinated a number of fall slash burning projects.

Allen F. Johnson, recipient of the 1988 Sandman IFC Memorial Scholarship, has been working in the forest protection area since 1977. During the 1977 to 1981 fire seasons, Allen worked as an initial attack crew member, an aerial detection observer, and as a helitack aide for the Ontario Ministry of Natural Resources (OMNR). From May 1982 to November 1983, Allen worked with private industry during the nonfire months and for the British Columbia Forest Service (BCFS) as an initial attack crew member and helitack crew leader. In 1984, Allen became a helitack crew leader with the Alberta Forest Service (AFS). Academically, Allen obtained a B.Sc. in forestry from Lakehead University in Thunder Bay, Ontario (1980) and an M.Sc. degree in forest fire science from the University of Alberta (1988). While at the University of Alberta, he was awarded the William A. McCardell Memorial Scholarship. He has successfully completed the AFS helitack crew leader and spotter training course, the BCFS 'Series 100' forest fire instructor's course, and the OMNR crew leader training course. Allen recently coauthored a paper entitled "Sample size and variability of fuel weight estimates in natural stands of lodgepole pine", which was published in the 1988 volume of the *Canadian Journal of Forest*

Research. Allen is currently a Forestry Instructor at the National Indian Forestry Institute at Meadow Lake, Saskatchewan.

1988 Sandman Fire Scholarship

Introductions by:

Dennis Quintilio
Alberta Department of Forestry, Lands and Wildlife
Forestry Technology School
Hinton, Alberta

On behalf of both Paul Woodard and myself and our respective institutions, I would like to extend our appreciation to the Interior West Fire Council for funding these student scholarships. It is gratifying to bring our outstanding students to such a distinguished forum relating to wildland fire management issues. The Forest Technology School (FTS) at Hinton offers a 2-year forestry program, which is recognized across Canada and demands a great deal of dedication and effort on the part of the students. The fire program requires 150 hours of classroom and lab time including an operational prescribed burn exercise and many challenging simulation exercises. I call them challenging. The students may have a few other appropriate adjectives. The students here tonight have excelled in both academics and practical skills in the fire program at FTS, and it is my pleasure to introduce them for their respective awards.

Edward Bend, co-recipient of the 1988 Sandman Fire scholarship, graduated this past spring from FTS and is currently employed with Sunpine Forest Products and his long range plans include tree farming here in Alberta. Ed graduated with an 83.5% average and submitted an outstanding fire control plan, which qualifies him for the award he is receiving this evening. Incidently, Ed won five of the nine awards available at our 1988 spring graduation ceremonies. He is indeed a credit to the forestry profession.

To give equal recognition to FTS students graduating between council meetings in Alberta, we have also selected the most outstanding student over the past five years (i.e., since the 1983 Intermountain Fire Council meeting held in Banff, Alberta).

Denise Krupa, co-recipient of the 1988 Sandman Fire Scholarship, graduated from FTS in 1986 with an 86% average and also submitted an outstanding fire control plan. Denise has been working in the forestry sector for six years. She has worked as a junior forest ranger in Kananaskis Country in 1983, an initial attack crew member in 1985 and 1986, and as a helitack/rappel crew member in 1987 and 1988. Denise's academic rating and her contribution to the fire control effort in Alberta since graduation certainly qualifies her for the award she is receiving this evening.

BANQUET ADDRESS

SOME PERSPECTIVES ON FOREST RESOURCES AND FIRE MANAGEMENT IN ALBERTA

Clifford B. Smith
Alberta Forest Service
Forestry, Lands and Wildlife
Edmonton, Alberta

ABSTRACT

The 1988 fire season was very significant to the western United States. The U.S. fire situation generated a high level of concern among Alberta Forest Service's fire managers. It helped to reinforce a long-argued policy—that of excluding unmanaged wildfire from the provincial fire management program. Alberta is currently experiencing an unprecedented boom in its forest industry, and by the end of the decade, the province's committed annual allowable cut will triple and over three billion dollars will be invested in new manufacturing facilities. This new development will bring true forest management to almost 90% of the provincial forested land base. At the same time, new demands will be placed on fire managers to avoid major campaign fire conflagrations and maintain provincial allowable burn standards. New directions and technology must continually be sought to meet these new challenges.

ADDRESS

Good evening ladies and gentleman. It gives me a great deal of pleasure to represent your host of this dinner—the government of Alberta. Although most of you have been here for the past two or three days, let me welcome you to the province of Alberta and specifically to Kananaskis Country. I would like to add my congratulations to Frank Platt, recipient of the 1988 Interior West Fire Council award for outstanding contributions to fire management. It was Frank's commitment, vision, and dedication that formed the basis for the modern system of forest fire protection in Alberta. I'd also like to congratulate the Interior West Fire Council student scholarship recipients for 1988—Denise Krupa, Ed Bend, Kim Clarke, and Allen Johnson.

I must admit that after years of involvement with the Intermountain Fire Council, I have difficulty getting used to your new name, the Interior West Fire Council. But I would like to congratulate you on your decision last year at Jackson, Wyoming, to consolidate the Rocky Mountain and Intermountain Fire councils. On this note, I would like to extend a warm welcome to those participants form Colorado, Kansas, Nebraska, North Dakota, and South Dakota—formerly members of the Rocky Mountain Fire Council. I view the amalgamation of the two councils as most progressive, and I'm sure that together you will bring a stronger voice to the Western Forestry and Conservation Association (WF & CA). As a trustee of the WF & CA, let me urge you to deal with matters of substance and get your resolutions to the Western Fire Committee. Only with strong support from this council can the WF & CA be effective in bringing about change where it is needed. A recent case in point is the September 8, 1988, decision by the U.S. Congress to provide a mechanism for payment for Canadian resources made available under the memorandum of understanding between the U.S. and Canadian federal governments for mutual aid. On the Canadian side, we have benefited for years from mutual aid made available through the Boise Interagency Fire Center and others, and we were somewhat frustrated that when we were in the position to return the favor we could not. The fact that the WF & CA, among others, were active in lobbying for this change was, I believe, partly instrumental for the decision. This makes for a win-win situation across the board.

Speaking of the fire situation in the Interior West and the Pacific Northwest, we did follow the situation very closely with a lot of interest, understanding, and sympathy. We have been there and could certainly relate to what you were going through. But let me assure you, it was not all in vain. In Alberta, we have been under pressure for some time to introduce a "let burn" policy, which in essence translates to the success we have had in controlling wildfire, especially in the Eastern Slopes. Often we are told that our old growth forests would not burn or in other words the "asbestos forest syndrome", so we didn't have to worry about them. We believe there is a place for wilderness, but like any other forest resource, it must be properly managed. Unmanaged wildfire, regardless of origin or intent, simply doesn't fit. There is simply too much at risk. What happened in the Yellowstone complex fires helped to reinforce our position that forest vegetation must be managed or altered through proper forest management, either through logging and prompt reforestation or through planned-ignition prescribed fires. Because wilderness or other protected areas are usually in close proximity to other values, we cannot afford to let wildfire roam at will.

This brings me to the end of the formal comments I wanted to make; however, I'm not going to let you off the hook that easily. When Marty Alexander assigned me the topic "Some perspectives on forest resources and fire management in Alberta," I thought it would be easy; but the problem is that it would probably take 3 hours to cover the topic. Also, I know what it's like to get through a couple of days of long, detailed technical presentations and then have to sit through another one after dinner. What I decided to do, therefore, was to put together some slides to give you an overview of where we are at with forestry and fire in Alberta. It is for the most part nontechnical in nature, but there are some messages, so put your feet up, loosen your ties, and don't worry, I'm as anxious to get to those hospitality suites as you are.

This evening I will cover the following subject areas:

1. Alberta's forests

2. Alberta's forest industry

3. The development thrust in forestry

4. Implications to fire management

5. Future needs in fire management

Many aspects of forestry will not be shown, for example, oil and gas operations, all of which have a bearing on our fire program, nor will other uses of the forest such as wildlife, watershed, grazing, and recreation, all of them important in the multiple-use matrix. In this respect, it's worth noting at this point that 27% of the Eastern Slopes area is protected from industrial development.

Alberta is a prairie province famous for its agriculture and petroleum industries. The question is often asked—Is forestry really that important in Alberta? Approximately 36 million hectares or close to 60% of the total area of the province is forested. The major softwood species are white spruce, lodgepole pine, black spruce, and jack pine. The major hardwood species are trembling aspen and balsam poplar. The minor tree species include Douglas-fir, balsam fir, limber pine, whitebark pine, larch (or tamarack), and white birch.

Alberta's forest resource is based on standing timber reserves of 2.5 billion m^3. The annual allowable cut (AAC) for softwoods and hardwoods amounts to 14.3 million m^3 (70% committed) and 11.4 million m^3 (25% committed), respectively. Alberta's forest industry ranks fourth in size in Canada behind British Columbia, Quebec, and Ontario (Table 1). The current value of our forest industry is 1.3 billion dollars.

In Alberta the forest industry has been somewhat slower to develop than in other regions of North America. There are several reasons for this: 1) the distance to markets; 2) the province is not on tide water; 3) much of the uncommitted resource is situated in the more remote areas of the province where there has until recently been little access and infrastructure; and 4) much of our resource is deciduous, which was until recently considered a weed. Alberta's economy has traditionally been developed from the strong natural resources involving agriculture and petroleum (oil and gas). In the mid 1980s, both petroleum and agriculture got into serious trouble in the marketplace. In 1986, in an effort to steer away from its dependence on these two resources, the Alberta government committed itself to a course of economic diversification and identified three main sectors as having strong potential for affecting diversification. These sectors were forestry, tourism, and science, technology, and telecommunications.

Forestry has led the way in accomplishing economic diversification. A number of factors contribute to the strong development potential of Alberta's forests:

1. Available uncommitted timber resources. Alberta is one of the last remaining areas in North America

Table 1. **The magnitude of Alberta's present forest industry**

Type of mill	Number of facilities	Annual production
Sawmill	169[a]	1.5 billion board feet
Bleach kraft pulp (BKP)	2[b]	0.5 million tonnes
Chemithermomechanical pulp (CTMP)	1	0.2 million tonnes
Plywood plant	3	230 million sq. ft.(3/8-in. basis)
Oriented strand board (OSB) plant[c]	3	600 million sq. ft.(3/8-in. basis)
Medium density fiberboard (MDF) plant[d]	1	50 million sq. ft. (3/4-in. basis)
Insulation board	1	65 million sq. ft.
Treated wood	9	40 million sq. ft.

[a] Approximately 50 of these are major producers. The largest sawmill is located at High Level and produces in excess of 220 million board feet annually.

[b] Third facility under construction.

[c] Canada's first OSB plant (based on aspen).

[d] Canada's first MDF plant.

with substantial volumes of uncommitted annual allowable cut.

2. Strong and secure timber tenure system. Alberta is recognized for its sustained yield and forest management programs (Fig. 1).

3. Strong track record in reforestation since 1966. For years Alberta has utilized a computerized tracking record for cutovers and has consistently achieved a 95% success rate in regenerating logged-over lands.

4. Low energy costs. Alberta is blessed with abundant energy resources. Natural gas is 40% cheaper than in other areas of Canada, and hydroelectric power costs, a major cost item for pulp mills, sawmills, and board plants, are also low.

5. Abundant water resources despite being a land-locked province. Alberta has several major river systems with large volumes of water flow that are essential for pulp development and are more than adequate to meet the province's already very high pollution control standards.

6. Stable labor force and competitive labor rates. This contributes to Alberta having the lowest delivered wood costs in Canada.

7. Low corporate taxes.

8. Excellent infrastructure support systems (i.e., highways, municipal centers, railways, airports) now in place.

There is one other major factor that I have not listed but that is vital if industry is to expand. We have been most fortunate to have exceptionally strong markets, particularly in pulp, so that major industries throughout the world have been looking for opportunities to expand. This has led to several major pulp and other forest industry projects, including the following:

- the doubling of Hinton's bleached kraft pulp (BKP) mill;
- Alberta's first chemithermomechanical pulp (CTMP) mill, which recently commenced production;
- a second CTMP mill complete with Alberta's first newsprint machine (now under construction);
- a new Greenfield 1000 t/day BKP mill based largely on aspen (now under construction);
- a third oriented strand board (OSB) plant and a recently approved particle board plant; and
- several sawmill projects.

All in all some 1.6 billion dollars of investment has been secured (Table 2). When all of these projects have been completed, in approximately 2 years time, we will have added close to 2900 jobs to our already existing 10 000 jobs in the primary forest industry. But

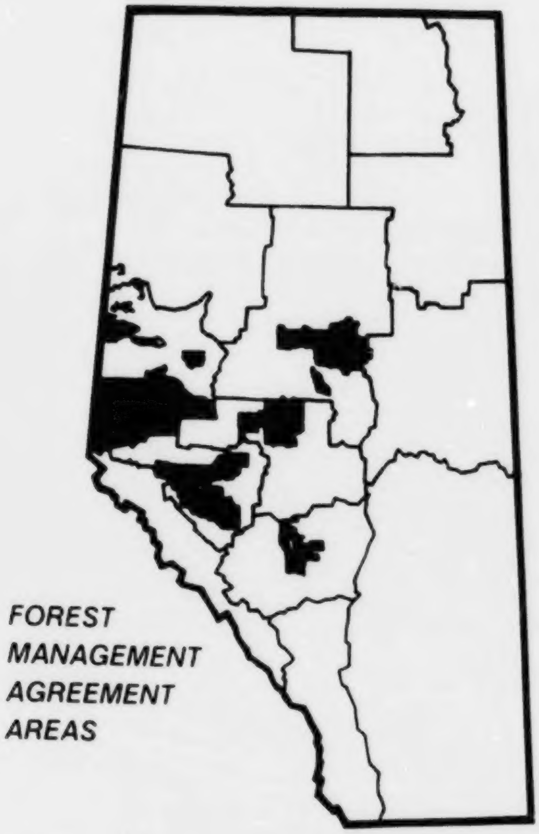

Figure 1. Existing Forest Management Agreement (FMA) areas in Alberta, 1988. FMA holdings are expected to increase significantly.

that's not all. Within the next 2 or 3 months I expect new major announcements of several more projects that will add an additional 1.5 billion dollars of investment and several more jobs. These include:

- a large BKP mill in northeastern Alberta with the possibility of a paper machine;
- a CTMP mill; and
- an 80 million board foot sawmill.

And beyond these short term developments, we are working with proponents for other possible projects such as:

- additional CTMP mills;
- possibly one more BKP mill;
- smaller pulp mills based on new technology; and
- additional panel board plants.

The end result of all this development is that we could be looking at 90% of our productive land base and AAC being committed as we enter the 1990s, which brings me to the subject we are gathered here to discuss—implications to fire management.

With the commitment of land base to the forest industry, we will no longer be in the position where we

Table 2. Major developments in Alberta's forest industry since the 1986 diversification thrust

Development	Number of jobs created	Capital investment ($ million)
Pulp		
Weldwood of Canada	510	400
Millar Western	191	200
Daishowa Canada	630	500
Paper		
Alberta Newsprint Co.	375	360
Panelboard		
Sunpine	267	32
Pelican Spruce Mills (OSB)	450	85
Sawmills		
Canfor Sawmill	N/A	35
Mostowich	40	88
Sawmill upgrades, etc.	75	15

can afford major campaign fire conflagrations. All tenure agreements with industry will have annual fire losses factored into the AAC. Beyond this, excessive fire losses can only be made up for through:

- improved utilization;
- intensive forest management to lift allowable cuts;
- increase in private woodlots to increase available purchase wood;
- salvage of fire-killed timber; or
- the worst-case scenario—reduced plant capacities.

Recent map compilations of Alberta's fire history clearly show the major influence of wildfire in the province, particularly throughout the northern boreal forest. In the 50-year period preceding 1980, 75% of the productive land base had been burned over. Much of the burned area has now been restored either to hardwood, softwood, or both. As we prepared to enter the 1980s, we were confident that we had a good fire control organization and strong capability; however, the 1980, 1981, and 1982 fire seasons in Alberta were characterized by some discouraging statistics:

- 4200 fire starts (over twice the average incidence);
- 2.6 million ha burned over;
- 73 million m^3 of wood destroyed;
- 170 million dollars in suppression costs;
- over 25 times the allowable burned area (i.e., 1/10 of one percent); and
- a 100-year drought cycle.

What we concluded was that although the organization was good, the overall capability was far from adequate. The serious fire losses experienced in the early 1980s indicated that a major upgrade of our fire management capability was needed. Major improvements and enhancements were deemed necessary if we were to maintain wood supplies for the existing industry. Fortunately, we had the commitment and support from the provincial government to help us to attain our goal. Since 1980 we have added the following in the way of major suppression resources:

- three DC-6 air tankers under contract;
- three B-26 air tankers under contract; and
- four CL-215 skimmer water bombers.

The water bombers were made available under a cooperative supply agreement with the Government of Canada that saw Alberta purchasing two CL-215s and the federal government purchasing two and dedicating them to the province under a "dry lease" agreement. We have been more than pleased with the CL-215. We remain firmly committed to land-based air tankers in the drier areas of the province but have found the CL-215 to be especially effective for sustained support action on extra-period fires. As a result, we are looking at acquiring two additional CL-215s, which we believe are necessary to protect the new commitments to the forest industry in Alberta.

For our land-based air tanker fleet (14 in total), we have added two new retardant bases, bringing the total number to 15. The CL-215s are also based at these tanker bases and usually load retardant for their first strike. We have also added 20 staging camps for preliminary basing of fire crews prior to dispatch to a fire. The primary camps include a cookhouse diner, sleeper, washhouse facilities, and tent frames for sleeping.

Contrary to most regions of North America, Alberta is still heavily committed to a fixed-detection network, which we feel is vital to complement our air patrol system. We have added two new towers, replaced others, and retired a few. In total, our fixed detection network consists of about 140 towers and lookouts.

The Alberta Forest Service has become active in helitack. We have added nine 7-man "HAC" crews and have contracted eight "medium" helicopters (Bell 205 and 212 variety). More importantly, we have added rappel capability to all of these crews in consideration of our vast unbroken tracts of timber. To support our rappeling operation we have built a rappel training tower at our Forest Technology School in Hinton.

In recognition of the lack of fire-fighting personnel in the Eastern Slopes area of the province, we have included three 25-person crews composed largely of university students. These crews can be broken into initial attack units or maintained as a complete unit for dispatch to campaign fires anywhere in the province.

In 1982 we completely replaced our teletype system with a state-of-the-art computerized system. Ironically, although this system has proven more than adequate, we now find that it is nearing obsolescence from a maintenance standpoint so we are now busily attempting to secure budget dollars to build a new system beginning in 1989.

In order to service our large fires, we developed two multicampaign fire kits based on the Ontario model.

Lightning detection has become a key ingredient to our initial attack system. Using lightning locator system technology and equipment, we have province-wide coverage. This currently consists of 11 direction finders, a central position analyzer at our Provincial Forest Fire Centre in Edmonton, and real-time monitors at all 10 of our forest headquarters locations. The system has been integrated with the province of British Columbia and the Northwest Territories.

We have also installed five remote automatic weather stations and have augmented these with several semiautomatic stations. All of these automatic stations complement our manual network of approximately 190 weather stations located at our lookout towers and ranger stations.

The enrichment program of the early 1980s also allowed us to bring the computer age into our fire management program with the purchase of 14 Apple III microcomputers which are now being replaced with IBM PCs.

As good as all of these new "toys" I have talked about are, the most important addition to our program has been the commitment from the government of Alberta to a presuppression preparedness resource system (PPRS). The most significant feature of the PPRS is that during periods of high to extreme fire danger, we must have suppression forces capable of actioning any newly reported fire within 15 minutes of discovery. The response time varies from 30 to 60 minutes under less critical burning conditions as determined by indexes of the Canadian Forest Fire Danger Rating System. The major features of the PPRS are:

- manpower and resources deployed to remote locations within 15-min attack zones;
- all crews to be rotary-winged equipped;
- resource deployment based on 24-hour fire weather forecast (i.e., crews put in place today based on tomorrow's forecast); and
- immediate resource demobilization with reduction in fire danger conditions.

A key feature of the system is that it allows us to carry out rotary-wing patrols with fire-fighting personnel on board, immediately behind lightning storm paths. This has paid back untold dividends in our initial attack success. The PPRS has enabled us to secure commitment from the provincial government to preposition resources in advance of an impending fire situation as a sort of insurance policy, the premium for which has cost an average of 10 million dollars per year.

The question is, "Has the PPRS been a success?" The answer: "Unequivocally yes." Over the past 5 years, fire losses have been less than half of the allowable burn area. Question: "Is this enough?" Answer: "Absolutely not!"

As I see it, our priorities in future fire management must include the following:

1. Bring fire management back into the forefront.

2. Maintain resource commitments and enhance the organization at every opportunity.

3. Gain public support through awareness and education.

4. Development new technology and equipment (i.e., R & D).

The priorities in research and technology are as follows:

1. Prevention
   - Physical aspects—vegetation management through prescribed burning.
   - Human aspects—public awareness through wildland-rural interface programs.

2. Presuppression
   - Fine tuning of fire danger indexes.
   - Development of additional fire behavior models for predicting fire spread and intensity in major fuel types.
   - Fuel inventory and type mapping.
   - Fire weather forecasting—evolution from an art to more of a science.

3. Detection
   - A major problem in Alberta, and a pet peeve of mine, is our inability to adequately detect holdover lightning fire starts. Recently, the Alberta Forest Service cooperated with the British Columbia Forest Service, the Canadian Interagency Forest Fire Centre, and Conair Aviation Ltd. in the evaluation of an infrared line scanner from Australia. Although some capability was demonstrated, it is not the total answer. What are we doing about improving the capability?

4. Initial attack
   - Includes the whole field (i.e., manpower, air tankers, helitankers, equipment).
   - The Alberta Forest Service has looked into the possibility of using indirect attack on fires where conventional initial attack methods would not be successful.
   - Obviously, we have a long way to go in manpower and resource capability if we hope to achieve this method in our highest priority areas.

5. Escaped fire suppression
   - Air tanker support—as I mentioned earlier, we have been pleased with the CL-215, particularly with the addition of foam capability. What new innovations and technology are we looking at on the land-based tanker side?
   - Indirect attack—a major priority from my perspective. A considerable amount of research, equipment development, and training will be necessary to expand our use of this tactic.
   - Equipment development.

As we expand our forest management program in Alberta, we must also address all of these priorities, and do it quickly, to protect the commitment and the downstream investment. Thank you for your attention this evening.

THE AUTHOR

CLIFF SMITH is the Assistant Deputy Minister responsible for the Alberta Forest Service (AFS) in the Alberta Department of Forestry, Lands and Wildlife in Edmonton, Alberta. He received his B.Sc. degree in forestry from the University of Montana (1963). Cliff worked briefly for the British Columbia Forest Service in site classification before joining the AFS in 1963 as Divisional Forester in the Peace River Forest, and he later worked in the AFS Timber Management and Woods Operations branches. Cliff was the Forest Superintendent of the Grande Prairie Forest between 1974 and 1980 before serving as the Director of the AFS Forest Protection Branch during 1981-85 prior to assuming his present position. He served as the vice-chairman and chairman of the Canadian Committee on Forest Fire Management from 1981 to 1984.

TECHNICAL SESSION III:

THE ROLE OF NEW TECHNOLOGIES, ANALYTICAL SYSTEMS, AND SUPPORT SERVICES IN FIRE MANAGEMENT ACTIVITIES

THE ROLE OF NEW TECHNOLOGIES, ANALYTICAL SYSTEMS, AND SUPPORT SERVICES IN FIRE MANAGEMENT

OPENING REMARKS

Moderator:
Alan M. Masters
Canadian Parks Service
Western Region
Calgary, Alberta

I was a shoo-in for this job of moderator because the conference coordinators knew well of my like for things silicon with lights, bells, and whistles. But am I really qualified to present a perspective on high technology, given that my career spans only 10 years? Shouldn't someone with 30 years in the business be better suited to stand up here and tell us how much things have changed? No! Technology and systems have changed so much even in the last year that all of us in this room are qualified for such a task.

In the Canadian Parks Service, for whom I labor day and night, we have seen the coming of the railroad, the automobile, the portable pump, the wireless telephone, the transition from horse-ranger to jet ranger, and (gasp) the resource management plan. Even in my short career I have seen the coming of mainframe and microcomputers, lightning detection systems, automatic weather stations, infrared scanners, thermologgers, and (shudder) more management plans, frames, schemes, strategies, and priorizing grids. We have seen that this change has been not just in boxes but also in systems. Advances in computer and software technology have in some cases outstripped the original system concepts (i.e., computers can now calculate fire danger ratings far more rapidly than resource allocation systems can respond) and multidisciplinary resource management planning scenarios are beginning to be met not with inflexible planning documents but simulation modeling that may foster a more adaptive management framework implicit on learning and embracing uncertainty about our knowledge and the future.

So what is the role of these new technologies and systems? For some of us, it's a living. For the financial controller it is to do the job cheaper. For the scientist or engineer it is to do the job better. For the manager, the role is to do the job faster; there are yet other jobs to do. But seriously folks, we really should not forget that for the ranger, warden, or technician, the role of these technologies and systems is simply to do the job, and allow him or her to get home safely and enjoy the social, economic, and artistic benefits of the natural resources you and I are paid to manage.

THE AUTHOR

AL MASTERS is the Regional Forester assigned to the Western Region office of the Canadian Parks Service (CPS), which is located in Calgary, Alberta. He received a B.Sc. degree in forestry from the University of British Columbia (1984) and became a member of the Alberta Association of Registered Professional Foresters in 1987. Prior to assuming his present position in 1985 he worked seasonally for the CPS as a park warden in Jasper National Park. Al also worked seasonally for the Alberta Forest Service in the Bow/Crow and Edson Forests and for Alberta Provincial Parks in Kananaskis Country. In his present position he has been focusing on fire management planning, developing vegetation programs, and coordinating the use of high-technology in fire management in the western national parks. Al is currently on temporary assignment to Kootenay National Park, which is headquartered at Radium, British Columbia, where he is involved in fire history and management project work.

LASER IGNITION: A NEW ERA IN WILDFIRE CONTROL AND PRESCRIBED BURNING?

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ABSTRACT

This paper presents an historical review of the concepts and developmental phases of the remote ignition of forest fuels by laser devices. An approximate 20-year developmental history is outlined that culminates with recent proposed concepts of laser ignition devices (LID). Some of these concepts appear to be approaching reality. Potential applications of these existing and proposed LIDs are given within the fields of wildfire control and prescribed burning as well as some uses in other areas of resource management are suggested.

INTRODUCTION

Before I enter into a review of the history of the development of laser ignition devices (LID), it is necessary to explain how a laser works. Most individuals have heard of lasers, but I have found that there is a general lack of understanding on what a laser really is. The name is really an abbreviation of the definition, Light Amplification by the Simulated Emission of Radiation. This process was one of the most exciting developments to come out of the physics laboratory during the 1960s, and the potentials of lasers are still just beginning to be realized. We now find lasers commonly in use not only in the physics laboratory but extensively throughout the medical field and industry and into such diverse areas as communications, surveying, grocery checkout stands, and even the music we listen to. It was only natural that the use of lasers also be investigated for the potential application in the art and science of fire management. It seems like we are always looking for that better match.

BACKGROUND INFORMATION

To understand how a laser works and what light amplification by the simulated emission of radiation means, it will be necessary to have a quick review of what is now considered elementary physics. Of course, back in the 1960s these concepts were not considered elementary at all but instead were at the forefront of a rapidly expanding science. We must go back to a description of the atom and how the various atomic components interact.

The atom is composed of a nucleus that is surrounded by orbiting electrons (Fig. 1). These electrons are arranged in rings or shells that are spaced successively farther away from the nucleus. Each shell has an individual capacity for a certain number of electrons; for example, the K shell, closest to the nucleus, can only contain a maximum of two electrons. The next shell (L) can contain eight electrons, the M shell a maximum of 18, and so on (Shields and Johnson 1981).

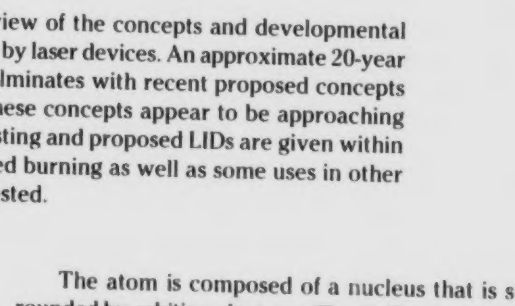


Figure 1. Atomic orbital energy levels (from Shields and Johnson 1981).

The amount of energy possessed by an orbiting electron is dependent upon the particular shell it occupies. Electrons in the K shell, the closest to the nucleus, contain the least amount of energy. The energy level increases for electrons occupying shells of increasing distance from the nucleus. This energy is derived from several sources, such as the motion of the electrons around the nucleus (kinetic energy) and the energy from the attraction of oppositely charged particles (potential energy). The energy level of an electron is restricted to very discrete steps. When an electron jumps from one energy level to another there is no intermediate level.

A change in an electron's energy level, either up or down, can be accomplished by the introduction of external electromagnetic energy, such as heat, light, or radio waves. This electromagnetic energy can be visualized as streaming energy packets known as photons (Fig. 2). The energy level of the photon is proportional to the frequency of the radiation. The intensity of the radiation is determined by the number of photons present in the stream of radiation.

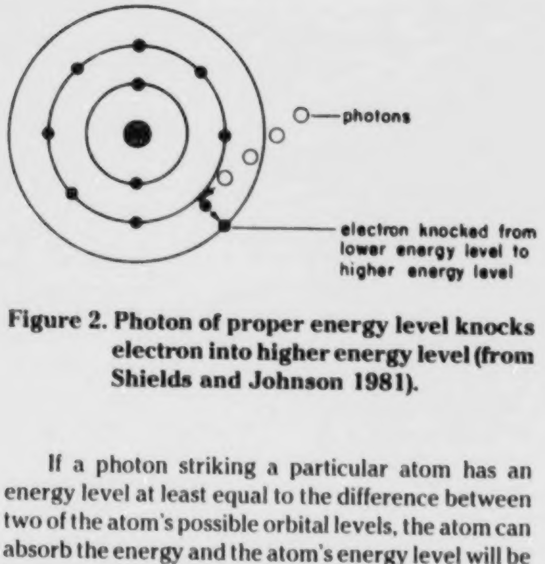
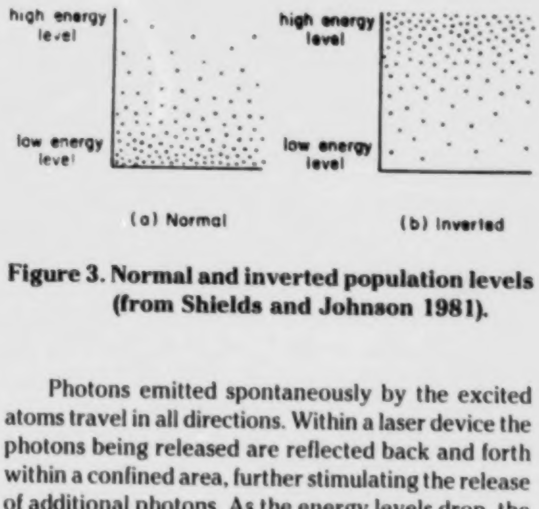

photons
electron knocked from lower energy level to higher energy level

Figure 2. Photon of proper energy level knocks electron into higher energy level (from Shields and Johnson 1981).

If a photon striking a particular atom has an energy level at least equal to the difference between two of the atom's possible orbital levels, the atom can absorb the energy and the atom's energy level will be increased from a lower energy state to a higher one. The absorption of a photon creates what is termed an excited atom. The reverse happens when the atom emits a photon, dropping the energy level to a lower state.

In most objects, the atoms have what is considered a normal population of energy distribution (Fig. 3). Most of the atoms are at stable low-energy levels, with a decreasing number of other atoms at successively higher energy states. If the atoms in the object can absorb photons, the absorption boosts the energy levels up to a higher state. If enough atoms become excited the object will develop an inverted energy population with more atoms at the higher energy levels than at the more normal low energy level. The process of adding photons to an object to create an inverted population is called pumping. Once an inverted population is reached it becomes increasingly difficult for the atoms within the object to absorb more photons. At this stage a passing photon can trigger, or stimulate, the release of a photon from an atom, dropping that atom back to a more stable lower energy level. This is called stimulated emission. The process leaves two free photons that can stimulate two other atoms releasing even more photons. The process is repeated until the object returns to the low-energy level with a normal population distribution. This amplification of the number of photons through stimulated emission can only occur in an object having an inverted energy population.



(a) Normal (b) Inverted

Figure 3. Normal and inverted population levels (from Shields and Johnson 1981).

Photons emitted spontaneously by the excited atoms travel in all directions. Within a laser device the photons being released are reflected back and forth within a confined area, further stimulating the release of additional photons. As the energy levels drop, the photons in the laser emerge through a hole in one of the reflective surfaces. These photons released from the laser form a beam of intense, coherent radiation that is the direct result of the stimulated emission. Coherent radiation is totally different from the radiation that we are normally familiar with from such sources as light bulbs and flames. Coherent radiation consists only of the one frequency or wavelength that is characteristic of the atoms emitting the photons. For lasers that emit a visible frequency we will see a single pure color such as red from the chromium ions in a ruby laser. Normal light consists of many frequencies of radiation producing what we perceive to be white visible light. Lasers are being manufactured that can emit radiation from the ultraviolet, through the visible, to the far infrared wavelength range. It is the lasers that emit radiation into the infrared, or heat range that interest us as an ignition device.

The laser characteristic of a concentrated narrow beam of a single wavelength is what has made this discovery so useful in the past. Now through advanced optics we are learning to take that narrow beam of radiation and focus it even narrower, allowing the energy to be concentrated within a specific location.

THE IGNITION DEVICE CONCEPT

It did not take very long after the discovery of the laser principles for the concept of using a laser to ignite both natural and activity fuel to be proposed. The earliest mention that I can find of the concept was by James Hickman in the late 1960s in Australia (Gellie 1983). This was only 8-9 years after laser principles were shown to work in the laboratories of the Hughes Corporation in 1960. In 1974, Hickman and Shepard started a series of meetings between the Physics Department of the University of Tasmania, Australia, and the Forestry Commission of Tasmania. The purpose of these meetings was to examine the feasibility of the development of a laser ignition device that would be able to ignite slashed eucalyptus fuel. In 1975 a joint research project between the two organizations was established under the guidance of Dr. Michael Waterworth.

A truck-mounted CO_2 laser-ignition device was designed and produced (Waterworth 1987). Following a series of experimental and design setbacks, field trials took place between 1979 and 1981. Varied success was obtained in igniting canvas targets at distances between 200 and 500 m over 20- to 60-second intervals. Power levels were deemed too low to obtain the "instantaneous" ignition strived for. The trials did confirm that the reverse Cassegrain telescope could focus the laser beam to the specified spot diameters at various distances. Further developmental work ensued (Gellie 1983).

A CO_2 laser system was selected by the University of Tasmania team over other laser types for several reasons. The CO_2 laser provided a remote infrared energy source with an energy level that was absorbed near the fuel rather than being dispersed. The infrared beam could be focused through a series of mirrors and optics. It was also the most efficient and safest commercial laser system that was available at the time.

By 1982 the University of Tasmania's laser ignition device had not been able to ignite eucalyptus leaves at distances over 750 m. Problems were also being encountered in achieving the perfect optical alignment necessary for the correct operation and adjustments were constantly needed. The team had encountered another basic problem: the LID was not proving to be rugged enough for work outside the laboratory, a very basic prerequisite for use in the business of forestry and fire management. So the team continued to develop and refine the LID to meet and better its performance under the conditions the device would be required to operate. Also at this time, replies to a survey that had been sent out to district and regional foresters in Tasmania indicated that many of them remained unconvinced of the suitability and flexibility of the LID in field operations (Gellie 1983).

In 1981 on the other side of the world a different approach to laser ignition was being attempted. Roy "Ernie" Johnson and Allen Graft of the USDA Forest Service in the Olympic National Forest were also convinced that lasers could be used as a safe method to ignite logging slash fuels (Graft and Johnson 1981). Their concept was to activate, by a very low intensity laser, a light sensitive switch, which in turn would activate an electric current to a squib or electronic match. The squib would ignite ignitor cord strips and Alumagel bags strategically placed throughout a prescribed burn unit. They field tested a hand- held argon laser aimed at the light sensitive switch surrounded by reflectors and found that the laser "gun" and switch system worked well on steep or hazardous ground. They also found that the system worked well during either the day or night but found that at night the reflective target background was especially easy to locate and hit with the laser. They did experience some problems with the preplaced targets. If burning of the unit was delayed the batteries could go dead, and disturbance also occurred from browsing mammals and mice. Plus the targets, if they did work, were destroyed in the resulting fire. The idea worked, however, and was probably the first true experiment illustrating the practical application of remote laser ignition. Ignitions were started at distances of up to approximately 1335 m, and the developers believed that distances up to 1600 m were feasible[1].

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[1] R.E. Johnson, Fuels Management Assistant, U.S. Dep. Agric., Forest Service, Olympic National Forest, Hood Canal Ranger District, Hoodsport, Washington, personal communication, March 18, 1988.

Johnson and Graft's experimental design was turned over to the private sector for further development and possible manufacture. Redeye Western Sensor of Coeur d'Alene, Idaho, modified the LID and called it the "Blazer." The company had considerable initial interest in the device, which was being designed to meet U.S. government specifications for use by various land management agencies. Their modified version reportedly hit targets up to 1600 m away with a beam 1.9 cm in diameter. Interest in this design dropped sharply, however, and the device was shelved after the 1985 announcement in North America that the University of Tasmania team had overcome their design setbacks[2].

The Australian developers now believed they had an LID rugged enough for extensive and extended field operations, powerful enough to ignite biomass at distances of up to 1500 m, and able to lay down an accurately placed line of "instantaneous" fire. It was claimed that their device could be focused at various distances to the burn unit and that the unit would ignite as the beam was panned across the fuel. A business-government consortium was being established to enter into the manufacturing and marketing phases. Plans were being developed to bring a prototype to North America during the spring of 1986 for demonstration purposes. These demonstrations were not to be. Dr. Waterworth's enthusiasm and optimism for the project had to endure numerous funding, legal, and construction delays. In late 1987 a private Australian company called Laser Dynamics Limited agreed to build and market the LID. Since that time a "blackout" on information about the LID has been enforced by the company as additional design development and building proceeded. Recent information from Dr. Waterworth indicates their desire to again offer demonstrations of the LID in North America during the spring or early summer of 1989[3]. Dr. Waterworth's persistence and determination for the LID project will bear fruit yet.

At the same time that initial interest in the Australian LID was peaking in North America, another laser ignition project was being presented. This project between the Canadian company AASTRA Aerospace, Inc. and a U.S. company called Physical Sciences, Inc. started in 1982. They were exploring the feasibility of using lasers to ignite oil spills on arctic melt pools (Frish et al. 1986). Their device was to be contained within a helicopter and would utilize a dual laser approach. A continuous wave CO_2 laser would be used to heat the oil film's surface and produce a combustible vapor. A pulsed laser would then be used to provide an ignition spark. Initial testing proved that the concept was feasible, and some of the technology and experience might have been useful in developing an LID aerial platform for truly remote ignitions. The aerial platform concept might also be necessary to help defray the LID hardware cost over more burn units per time to ignite those units. The research was delayed with a downturn in the price of crude oil, which had provided the primary funding source[4].

WHAT DOES THE FUTURE HOLD FOR LASER IGNITION DEVICES?

Research on lasers is progressing rapidly in many fields, and at this point it is difficult to tell where it will all end up. It seems likely that we may have an operational CO_2 LID in North America by next year. It is also quite evident that the size and weight of lasers and their supporting equipment are dropping, their energy output is increasing, and problems concerning laser efficiency and cooling are being tackled. Research is also progressing in such promising areas as diode lasers, which may be much more compact, lighter in weight, and potentially more high powered than CO_2 lasers; and in masers, a similar and older technology to lasers using microwaves. Research into high-powered laser aerial platforms is proceeding rapidly, especially in the military. The military is reportedly testing high-powered lasers for use in communications between aerial platforms and submarines, antisubmarine warfare, and for the destruction of underwater mines. As with other emerging technologies that are finding increasing use in the private sector, the prices of lasers have been dropping compared to similar equipment 5 years ago. These prices will likely continue to decline as manufacturing and use of lasers increases. Operational and safety concerns for an LID will have to be evaluated as the equipment becomes available. Currently some of the limitation concerns might include the following:

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[2] G. Hogan, Redeye Western Sensor, Coeur d'Alene, Idaho, personal communication, June 1, 1988.

[3] M.D. Waterworth, Department of Physics, University of Tasmania, Hobart, Tasmania, Australia, personal communication, September 27, 1988.

[4] H. Scholaert, AASTRA Aerospace, Ottawa, Ontario, personal communication, June 6, 1988.

1. Will the LID be rugged enough for extended outdoor use in rough terrain and inclement weather?

2. What accuracy will the LID have in laying down a line of fire in discontinuous fuel or fuel distributed at various angles to the beam?

3. How much will the hardware cost and how long will it take to recover that cost in operations?

4. How much will varying densities of smoke interfere with beam penetration and ignition?

5. If accuracy is important will aerial platforms be stable enough?

The following are possible advantages of using an LID over other ignition procedures:

1. Elimination of the need for human ignitors within a burn unit's perimeter, permitting ignition crews to avoid physical hazards such as smoke, flames, and rolling logs.

2. There is no need for extensive ground crews and ground support systems in LID equipment operation.

3. Fire intensity and placement can be closely regulated and adjusted by a single individual at a remote distance from the unit.

4. No hazardous fluids or chemicals mixes to initiate combustion are carried within the aerial platform.

5. Focused beam and tracking system aids in maintaining the ignition pattern within the desired burn unit and reflected unfocused beam is unlikely to harm either the ground or air crews.

6. There is the potential to ignite more than one unit from a single location or the rapid deployment of LID through the use of an aerial platform.

7. The aerial platform could also serve as a reconnaissance aircraft for the evaluation of fire behavior.

8. There is potential for improved economy through reduced costs and improved safety of personnel.

The potential for improved economy will also depend on how many other uses the LID might have besides what the majority of the research has been directed toward, the ignition of activity fuel. It might prove to be very uneconomical if after purchasing an LID it remained unused 6 months of the year. Other uses will have to be found for an LID if the current initial large capital expenditure is to be justified. At the moment we have not had the opportunity to witness an LID in operation, so its potential for other operations is unknown. But considering some of the advertised qualities of the LID, with a little bit of imagination we can consider some interesting possibilities.

Of course, the first application that comes to mind would be the potential use of an LID in a wildfire suppression action. An LID could provide rapid backfiring operations in rough terrain or where the working conditions would be unsafe for ground crews. An aerial platform could provide a very rapid response for this type of activity and a greater flexibility in ignition possibilities. In combination with an infrared scope for locating fire, an LID could be used for the remote ignition and burnout of fuel within a wildfire perimeter or for the ignition of fuel under smoky conditions created by inversions.

Another possibility is use of the device for the economic prescribed burning of large areas for ecosystem maintenance or vegetation manipulation that has been proposed and initiated on some national forests in the United States. An LID could be used to provide selective spot ignitions through the forest canopy, minimizing overstory damage that might have resulted from the use of an ignition device other than an LID. An aerial LID would also provide access to remote areas, eliminating the need for fuel and torch transportation and making the burning of remote sites more feasible and safer. The LID could be used in all fuel types and in areas of discontinuous fuel, where use of some ignition devices is currently limited.

Uses of an LID at other times of the year, and uses that do not include fire are subject to current limitations on our imagination. A few potential uses, based again on advertised capabilities, might include tree or brush thinning and pruning, tree topping for wildlife snags, cavity starts for cavity nesting birds, and the precise selection of conifer cones for nursery seed collection.

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THE AUTHORS

CHUCK BUSHEY is the President of Montana Prescribed Fire Service Inc., which is headquartered in Missoula, Montana. As a prescribed fire specialist/fire ecologist, Chuck has a background in fire behavior, fire behavior modeling, fire effects, fuel inventories, prescribed fire operations; with additional training in vegetation analysis, wildlife management, land-use planning and aerial photo interpretation. Chuck received a B.A. degree in biology from Monmouth College (1973) and an M.Sc. degree in botany from Southern Illinois University (1985). Chuck has worked as a Biologist for the Lake Country Forest Preserve District (Libertyville, IL), as a Botanist for Hazleton Environmental Sciences (Northbrook, IL), and as a Biological Technician with the Fire Effects & Use Research and Development Program at the Intermountain Fire Sciences Laboratory (formerly Northern Forest Fire Laboratory) in Missoula, Montana. During the 1988 fire season, he was responsible for the Northern Rocky Mountain Region RICO, Fire Behavior Service Center. Chuck is also currently a Research Botanist with Systems for Environmental Management of Missoula, Montana, a nonprofit fire research organization.

SONNY STIGER is a Vice President (Administration) with Montana Prescribed Fire Services Inc. located in the firm's branch office at Wolf Creek, Montana. As a prescribed fire specialist, Sonny has a background in wilderness fire management, prescribed fire operations, wildfire suppression, fire behavior, fire behavior modeling, fire effects, fuel inventories, and fire management planning. He received a B.Sc. degree in forestry from Colorado State University (1959). Sonny was a former District Ranger with the U.S. Forest Service at Estes Park, Colorado, and served as the Timber and Fire Staff Officer position in the supervisor's office of the Arapaho-Roosevelt National Forest in Fort Collins, Colorado. Also during this time he was the Fire Management Coordinator for the Northern Colorado Front Range Fire Alliance involving three county organizations—the Colorado State Forest Service, Bureau of Land Management, and Rocky Mountain National Park. In 1977 he assumed the position as the Eastside Zone Fuel Specialist in the Northern Region of the Forest Service, with responsibility for fuel inventories and developing fire management plans on four National Forests. Sonny has been involved as a member of the overhead team on several large wildfire suppression actions and has received numerous commendations. During the 1988 fire season, he acted as a wilderness fire monitor, then later as a temporary acting fire management officer for the Rocky Mountain Ranger District of the Lewis and Clark National Forest.

POTENTIAL OF VIDEODISC/MICROCOMPUTER TECHNOLOGY IN FIRE TRAINING

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ABSTRACT

Interactive video is a powerful medium, bringing together the emotional impact of video film and the interactive capabilities of the computer. Interactive videodisc instruction can be used as a tutorial for drill and practice and in simulations as well as for information storage. Videodisc technology is being used in industrial, military, and medical applications for training, sales, education, and information systems. Interactive videodisc technology has been used to produce a training program in beginning, intermediate, and advanced wildland fire behavior. The program utilizes stills, motion video, audio, computer graphics, and includes quizzes and computer graded unit final exams. It was programmed using the Quest authoring system and is delivered via an IBM PC computer in a completely interactive level three format. Field testing is presently underway to evaluate the effectiveness of material delivered using this technology.

INTRODUCTION

In recent years, fire research has developed a large body of complex information. Proper wildland fire management and use requires a thorough understanding of combustion, fire behavior, fire ecology and history, fire economics, fire effects, and prescribed fire practices.

Large areas of valuable resources and human lives are often at stake during prescribed fire and fire suppression activities, making thorough, up-to-date professional training essential. Fire fighting can be physically demanding, dangerous work, requiring not only physical stamina, but a complete understanding of how to react appropriately to fire conditions. Because safety is such an overriding concern, adequate training is mandatory to reduce risk.

Most fire management organizations require approximately 40 hours of formal training as a basic prerequisite to any entry level suppression position. The curriculum includes fundamentals of fire behavior, fire suppression, fire organization, tool and equipment use, and safety. Fire behavior is central to this curriculum, and a subject taught by all fire management agencies. Fire behavior has proven to be a stable, well developed course of study, and a complete, multi-level instructional package has been developed by the National Wildfire Coordinating Group (NWCG), which is the training standard in fire behavior for all NWCG agencies. For these reasons, fire behavior was chosen as the topic for this project.

The project involved using existing fire behavior curricula in an interactive videodisc/computer training system. This disc supplements existing training courses in wildland fire behavior, and includes material produced by NWCG on introductory (S-190), intermediate (S-390), and advanced (S-590) fire behavior.

The project demonstrates the application of interactive videodisc instruction to wildland fire management by providing a complete training package on wildland fire behavior. The program does not replace existing instructional materials, but acts as a supplement to current training materials.

INTERACTIVE TRAINING AND INSTRUCTION

Basic principles of interactive design must be clearly understood in order to realize the benefits of an interactive training medium. Too many course developers inappropriately think that interactive instruction requires nothing more from the learner than pushing a button on the keyboard, or performing a particular motor response. As most people know from experience, a person can have a high degree of involvement even when no obvious motor response is performed in activities such as listening to a symphony concert, or watching an absorbing drama. By the same token, a boring and unresponsive instructional program will not be saved by the opportunity for a learner to push a few buttons. In order to provide useful interaction between the learner and the instructional program, intellectual options should be provided that allow users to actively make decisions and be subjected to their consequences (Bosco 1984). For example, an incorrect calculation of a fire's rate of spread in a given simulation may result in seeing a fire crew abandon equipment in a hasty retreat. Learners make choices, and the system responds, sometimes in surprising ways. An interactive videodisc lesson should allow learners to "create" their own training experience. In this context, it can be defined as:

> A form of computer and videodisc-based instruction, which allows learners to intervene and make frequent decisions about the content of the lesson and the way it is delivered.

The instructional system responds instantly to learner input by providing relevant, previously-designed instructional cues, reinforcement, and feedback segments related to desired concepts, comprising computer text and graphics, still and motion video, with or without audio. The scope, sequence, rate, style, duration, level, and medium of instruction is, to a large degree, determined by a dialogue between the learner and the system.

The linear, presequenced format of most traditional instructional formats such as texts, workbooks, films, or slide/tape presentations treat all learners alike, and do not allow the learner to actively take part in the choice of sequence or content of a lesson (DeBloois 1982). The quality of interactive instruction in combination with the sophisticated video/audio capabilities of television make this medium a potentially powerful tool for instruction.

Interactive video is a powerful medium, bringing together the emotional impact of video and film, and the interactive capabilities of the computer. Development of interactive videodisc instruction has, to a large degree, mirrored computer-assisted instruction (CAI). Like CAI, interactive video-disc instruction can be used as a tutorial, for drill and practice and in simulations, as well as for information storage.

DESIGNING INTERACTIVE VIDEODISC INSTRUCTION

The process of designing, writing, directing, and producing an interactive videodisc/computer lesson in wildland fire behavior was very similar to the basic design and production of an instructional film. However, the major challenge was the integration of various media, designing the dynamic relationship between the user and the system, and working with a modular, rather than linear medium (Fig. 1).

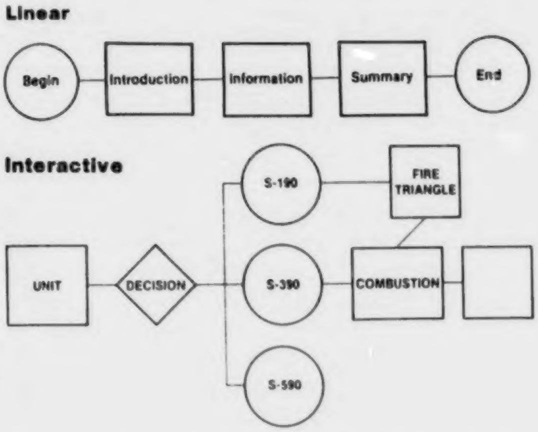


Figure 1. Linear vs. interactive instruction (from Daynes 1982). A linear program has a presequenced format. An interactive program allows learners to make choices.

Instructional Matrix

A content matrix for the instructional package in wildland fire behavior was initially developed from a careful analysis of program goals and objectives, existing course materials, learner characteristics, and the various forms of media used within the disc to be selected. This matrix listed the appropriate instructional segments classified by topic and intended learner group in a matrix structure. The matrix thus acted as a map, which guided the designer in creating the dynamic flow chart that represents the interactive branching training program.

Interactive instruction is designed to be modular and nonlinear, with hundreds of preplanned options available to learners based on prior knowledge of their unique interests, abilities, feedback preferences, primary language ability, and learning styles.

Branching

Videodisc interactivity is made possible through a process called branching. A branching program has alternate tracks for the rapid and slow learner; it can follow up certain responses in detail, allow learners to see only the materials they need or want to see, test learners on the comprehension of the materials, allow learners to repeat material or to have remedial work when needed, and effectively pose a question without demanding one specific, correct answer. Although branching has been extensively used in computer-assisted instruction, there have been weaknesses in the quality of video imagery and search time for sequences, which have proved to be somewhat disruptive to learning. The introduction of videodisc technology has been an obvious and practical solution to these problems.

Flow Charting

The branching system developed for the instruction was graphically represented as a flow chart. The flow chart depicted all instructional events included in the wildland fire behavior training program for the various specified audiences. The flow chart showed each instructional frame, both still frames and motion sequences, all branching options, menu driven and under program control, all "help" routines, all test items, and dedicated jump forward and review options.

The procedures used in flow charting interactive instruction were similar to those used in any flow charting operation. Symbols are very nearly the same, with a few variations which allowed for easy identification of the nature of the instructional frame, whether it is a still or freeze frame, or motion sequence. A sample flow chart is shown in Figure 2 to demonstrate the complexity involved in the development of an interactive lesson in wildland fire behavior.

Successful design and implementation of a flow chart was the most time-consuming and difficult task in the design and production process. One of the key strategies for successfully creating an interactive videodisc-based lesson was able to map out the various instructional options for the different targeted learner groups in a flow chart.

Script, Narrative Writing, and Graphics

After the major elements of flow chart construction were completed, scripts and narratives were written, including all text, computer and quiz screens, and test items. Special terms were used to help integrate the various media, and keep track of hundreds of instructional segments used to individualize instruction for the variety of learners who will use the disc. Scripts and storyboards were then drafted and reviewed for content, style, and feasibility; graphics, animation, and special effects are also planned at this time. Formative evaluation and revision were important during this stage of design. A storyboard form was developed to represent the specific content of each frame and was the primary tool used by the computer programmer to integrate the various media and to develop branching sequences (Fig. 3). Approximately 1500 such forms were developed and used in producing this training package.

Preproduction

The preproduction phase of an interactive videodisc was very similar to that of a film or videotape. There were, however, some steps unique to the videodisc medium, including the mapping of the "geographical" layout of the disc, and locating the simple time code numbers for the video frames from the master tape. These steps were completed before the final production and mastering of the videodisc (Daynes 1982; Nugent 1982).

Production details will not be discussed, as basic production for videodisc is almost identical to that of other media such as videotape or film. Once a master videotape of the training materials was edited, the tape was sent to a mastering house, where the visual images and audio were transferred onto a videodisc. An initial check disc was produced and a later revised check disc was used for programming and field testing. The final disc contains nearly 50 000 frames including 430 slides, 275 computer graphics, and 25 minutes of 125 motion video sequences, much of it with narration or ambient sound.

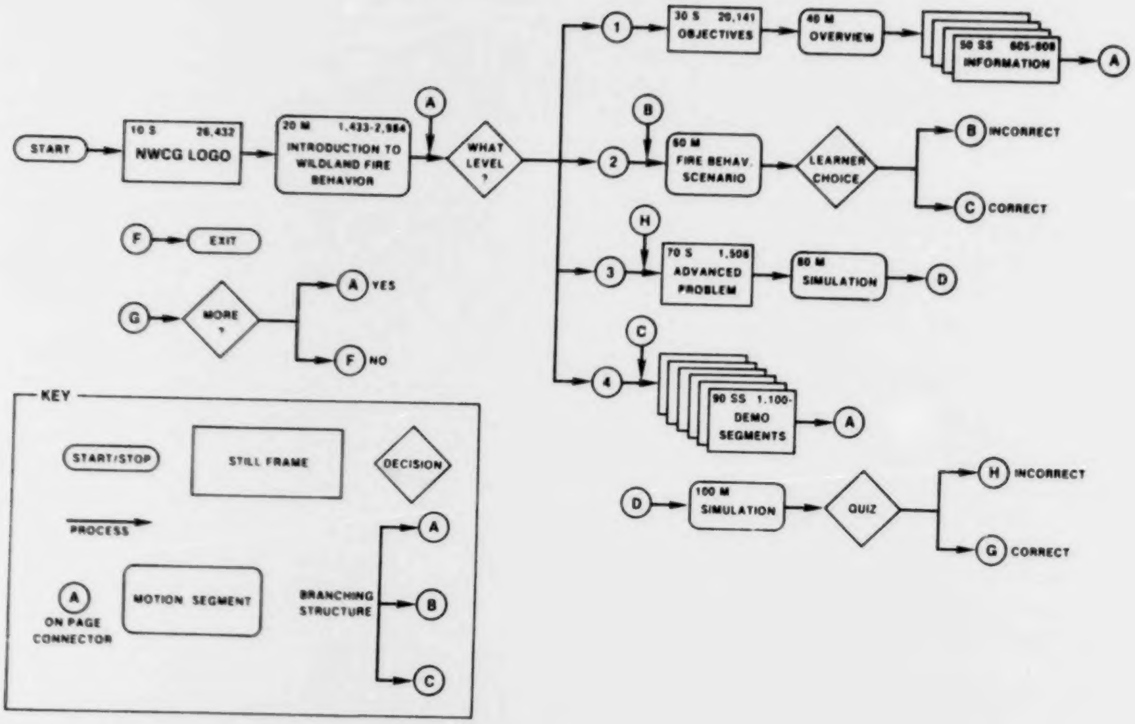

START
10 S 26,432
NWCG LOGO
20 M 1,433-2,984
INTRODUCTION TO WILDLAND FIRE BEHAVIOR
A
WHAT LEVEL ?
1
30 S 20,141
OBJECTIVES
40 M
OVERVIEW
50 SS 605-608
INFORMATION
A
2
B
60 M
FIRE BEHAV. SCENARIO
LEARNER CHOICE
B INCORRECT
C CORRECT
3
H
70 S 1,506
ADVANCED PROBLEM
80 M
SIMULATION
D
4
C
90 SS 1,100-
DEMO SEGMENTS
A
D
100 M
SIMULATION
QUIZ
H INCORRECT
G CORRECT
F
EXIT
G
MORE ?
A YES
F NO
KEY
START/STOP
STILL FRAME
DECISION
PROCESS
A
ON PAGE CONNECTOR
MOTION SEGMENT
BRANCHING STRUCTURE
A
B
C

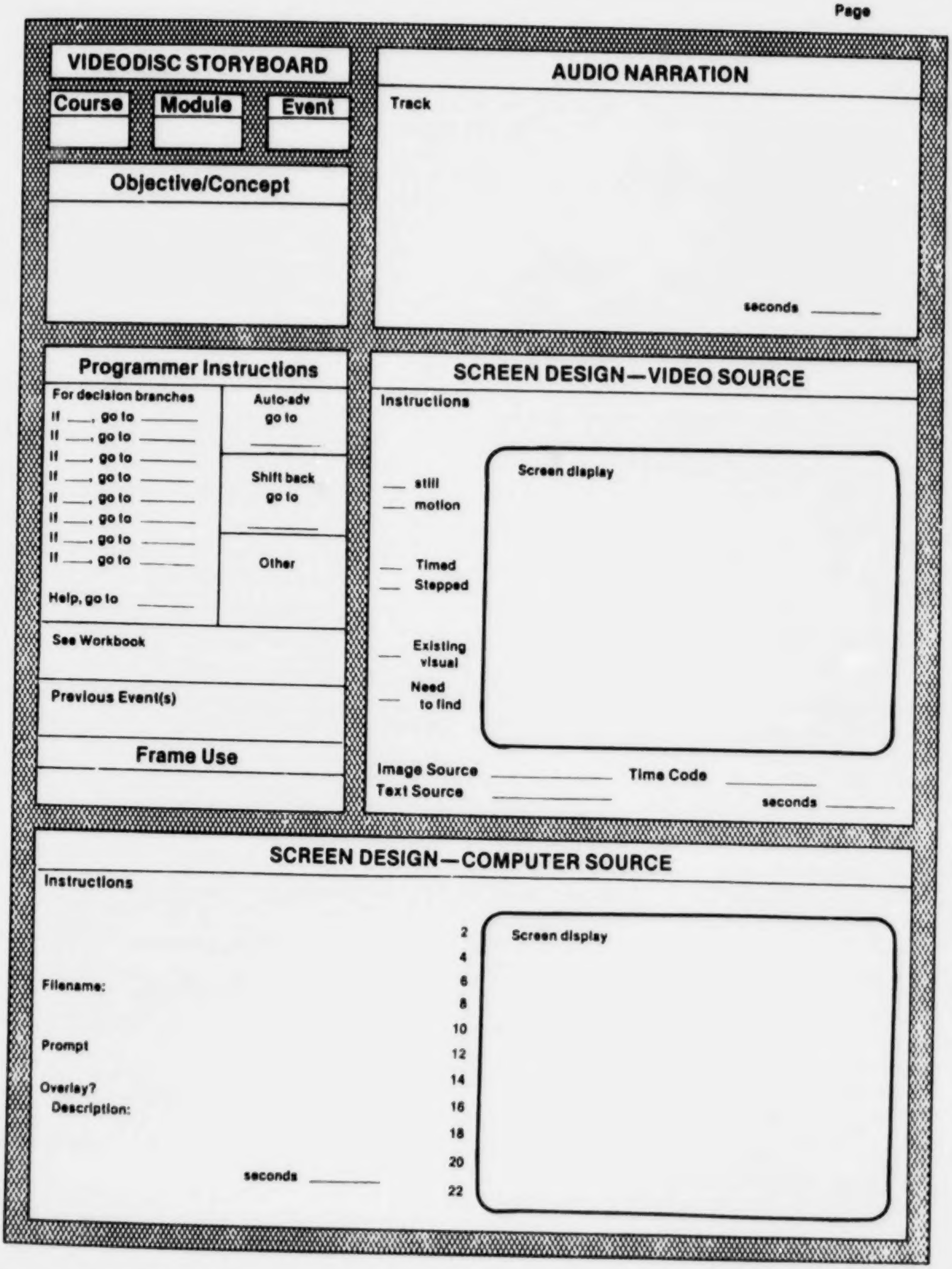
Figure 2. A sample flow chart showing the complexity of the development of an interactive lesson.

HARDWARE AND SOFTWARE CONSIDERATIONS

The delivery system used for the fire behavior training program consists of an IBM personal computer with a 20 megabyte hard disc interfaced with a Pioneer videodisc player. The system utilizes a single Zenith RGB color monitor allowing computer text to be placed over video from the videodisc player (Fig. 4). Computer programming was accomplished with the Quest authoring system, which was used to create over 2500 frames of instruction for the introductory, intermediate, and advanced levels of instruction.

BENEFITS OF INTERACTIVE VIDEODISC TO FIRE TRAINING

Interactive videodisc technology has proven to be a powerful educational tool, using computer-based learning systems that can display high-quality video imagery, provide rapid access to images, and utilize quality audio. The individualized, self-paced format represented by videodisc instruction focuses on learner needs, rather than predetermined pace and sequence. A learner is able to choose among a variety of instructional options, and learning is directed according to their performance and measurements of



Page

VIDEODISC STORYBOARD

Course **Module** **Event**

Objective/Concept

AUDIO NARRATION

Track

seconds ________

Programmer Instructions

For decision branches
If ___, go to ______
If ___, go to ______
If ___, go to ______
If ___, go to ______
If ___, go to ______
If ___, go to ______
If ___, go to ______
If ___, go to ______

Help, go to ______

Auto-adv
go to ______

Shift back
go to ______

Other

See Workbook

Previous Event(s)

Frame Use

SCREEN DESIGN—VIDEO SOURCE

Instructions

___ still
___ motion

___ Timed
___ Stepped

___ Existing visual
___ Need to find

Screen display

Image Source ________ Time Code ________
Text Source ________
seconds ________

SCREEN DESIGN—COMPUTER SOURCE

Instructions

Filename:

Prompt

Overlay?
Description:

seconds ________

2
4
6
8
10
12
14
16
18
20
22

Screen display

Figure 3. Sample storyboard from developed and used for the videodisc fire behavior training program.

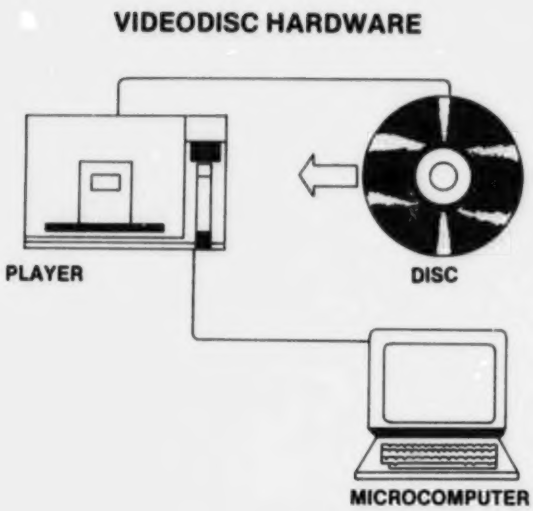


Figure 4. Hardware components of an interactive videodisc/microcomputer system.

their understanding. Interactive videodisc allows learners to have remedial work when needed, or skip ahead if prior mastery is demonstrated.

Other benefits of using interactive systems include the use of programs by either individuals or small groups, flexible scheduling of training, the portability and ease of transport of instruction to remote training sites, and the savings of training costs at a fraction of the cost of traditional training methods.

Studies are underway to compare videodisc instruction to traditional methods of fire behavior instruction and may show numerous advantages from the use of interactive videodisc. Factors such as savings in actual learning time, higher mastery rate, and favorable response to the medium all prove to be significant factors in the use of interactive instruction. Other cost related benefits include less time away from the job, reduced travel/living expenses for training, reduction of classroom instructors, and use in remote training stations (Ebner 1984; Glenn et al. 1984).

Fire behavior training naturally lends itself to the videodisc medium. Because of the huge storage capacity of a videodisc, beginning, intermediate, and advanced fire behavior training courses could be placed on one disc, allowing the learner to seek remedial help when necessary, or go on to advanced material when desired. The incorporation of tutorial lessons, as well as drill and practice, test items, and information storage make interactive videodisc an efficient, space-saving medium for instruction. By providing training at a fraction of the cost of traditional methods (not including development costs), interactive training systems may become a powerful training tool for fire managers and personnel.

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OPERATIONAL INFRARED SURVEILLANCE AND MONITORING OF WILDLAND FIRES

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ABSTRACT

This paper reviews the operational experience with a combination infrared (IR)/video scanning system acquired by the Billings Area Office of the USDI Bureau of Indian Affairs in 1985. The system combines the capabilities of IR sensing with videotape recording and is designed to be mounted on a base affixed to the rear seat of a helicopter for aerial scanning purposes. A description of the system's components is recounted. Potential and actual applications/uses of the system are briefly described, including a discussion of implementation considerations and future developments.

INTRODUCTION

Ladies and gentlemen, it's a pleasure to be here today. I think our Canadian hosts should feel proud to have put on such an excellent session this week, in such a beautiful place, complete with yesterday's snowstorm!

This morning I'd like to describe for you a commercially available infrared (IR)/video scanning system that is being used to locate and identify hotspots on both uncontained wildfires and wildland fires that are in the mop-up stage. The trade name for the system is AVIOSS, which stands for Aerial Video Infrared Overlay Scanning System. The Billings Area Office of the USDI Bureau of Indian Affairs purchased the first complete system in the United States. Russell Davis, a fire management officer with the BIA office in Billings, Montana, was largely responsible for the system's acquisition and subsequent use as a tool in fire management operations. There are currently five other AVIOSS units operating in the United States. The USDI Bureau of Land Management in Roseburg, Oregon, has one. The USDA Forest Service has four complete units: one each on the Olympic National Forest in northwestern Washington, the Shasta-Trinity National Forest in northern California, the Willamette National Forest in western Oregon, and the Flathead National Forest in northwestern Montana.

SYSTEM COMPONENTS AND PRICE

Let me briefly tell you what the AVIOSS is all about. The system is made up of the following components:

- video camera and video cassette recorder (VCR)
- model 650 Probeye IR viewer
- thermal printer
- TV monitor
- power supply

The system is mounted on a base affixed to the right rear seat of either a Bell 206 or a Hughes 500 helicopter (the door must be removed during scanning missions). The base swivels and moves outside the helicopter so that the operator can move the video camera and Probeye viewer either back and forth or up and down. This eliminates having to hand hold the Probeye for extended periods during a scanning mission. The total weight of the system components used in the helicopter is about 55 kg, and it generally takes around 10 minutes or less to install it.

The video camera is equipped with a 10× power 200-m lens, which is preferred to the standard 6× power lens, since it allows for low light capability during early morning hours, which is the best time of the day for IR scanning (i.e., before surface heating begins).

The zoom lens allows the system operator to have a close-up look at possible target areas or a distant look at other important parts of the fire.

The model 650 Probeye IR viewer detects visible infrared radiation (i.e., heat) and converts this energy to visible light (Barney et al. 1979). Hotspots, which are not visible to the naked eye, can be detected by superimposing the IR imagery from the Probeye viewer and the black-and-white video imagery of the ground surface or background view. Quick release mounts for the Probeye allow for ease in mounting and removal for storage or in carrying out ground inspections with the IR viewer. With the VCR, the overlay is captured on videotape for later viewing, documentation and mapping, or for instant replay directly on-site. The thermal printer will produce 7.6 × 12.7-cm black-and-white prints of the infrared overlay. The TV monitor allows the system operator to see what is being filmed and to observe hotspots on a real-time basis. The videotape can also be a valuable aid in training system operators.

The system's power supply component includes a 24-volt to 12-volt direct current (DC) converter, which enables the system to run directly off a helicopter's power source. There is also a rechargeable battery pack that permits the system to run independently when live power is not readily available.

The complete system as described above will cost from $U.S.22,000 to $U.S.25,000. Glen Hogan, of Redeye Enterprises of Coeur d'Alene, Idaho, is the person to contact for further information on the AVIOSS unit. He knows the Canadian outlet for the system and will gladly provide you with their address, literature, and more specific costing. The company that sells the AVIOSS unit will provide all the necessary training to get new purchasers started. A company representative will spend a minimum of one working day going over the entire operation of the system. A classroom session is also available.

OPERATING PROCEDURES AND CONSIDERATIONS

The system can be operated by the helicopter pilot and one operator. It is best, however, to have an observer along as well. The system operator runs the video camera and controls from the left rear seat of the helicopter. The observer sits up front and monitors the flight path taken during the scanning mission. When a scanning mission is completed, the videotape is shown to the overhead team assigned to the fire and then later a map is produced. When the BIA office in Billings first acquired the system, there was no audio in the unit. This caused problems when the videotape was being viewed because it was difficult to continually locate oneself with respect to the fire area. The same problems arose later when preparing a map of the hotspots in the fire area. In 1987, the BIA office in Billings added audio capability to the camera and now the observer simply speaks into a recording microphone, identifying features, locations, air speed and direction, etc., as the helicopter flies along a given route. There is now much better interpretation of the flight path, position of the fire and fire behavior.

One minor disadvantage of the AVIOSS unit as compared to nighttime flight operations with IR line scanners mounted in fixed-wing aircraft (Warren and Wilson 1981) is that the videotapes resulting from the scanning missions are not available for early morning briefings of fire fighting personnel. The results, however, can be viewed later in the morning by pertinent line staff. The use of video seems to enhance the intelligence information gained by the IR sensing.

What about storage and portability? The entire system can be housed in four containers, which are available from the manufacturer. The containers and all of the system components weigh about 160 kg. The entire packaged unit can be air transported but the BIA office in Billings prefer to use a van for transportation to a fire camp or heliport location. There should not be any problems with several agencies in a certain geographical region sharing one unit. It must, however, be stationed where someone can make sure it is always kept ready for dispatch to a fire incident.

THE SYSTEM IN USE

The system is starting to gain acceptance with incident command teams requesting its use now that they've seen the results that can be obtained. The Billings AVIOSS unit was used eight times during the 1988 fire season. It has application on both very large project fires like the Clover-Mist Fire in northwestern Wyoming, and on smaller fires of less complexity, when there is a helicopter available. Regardless of the fire size, the AVIOSS unit can help identify potential problem areas with each fire.

Here are two specific examples of how valuable the system can be in fire management and in other applications. In Oregon, a random-ignition prescribed fire in a wilderness area was threatening to spread onto an adjacent reservation and because of heavy smoke, no one could see what the fire was doing. Information was obtained inspite of the smoke pall with the use of an AVIOSS unit. Hotspots were detected downwind of the main fire front and this assisted in planning a strategy to deal with the fire. In California, the USDA Forest Service had undertaken a planned-ignition prescribed fire and when it had finally burnt itself out, the perimeter was scanned with an AVIOSS unit. No hotspots were found. A day or so later, a lumber operator accidentally started a fire, but tried to blame it on a restart from the prescribed fire; however, when the videotape from the scanning mission was shown in court, with no discernible hotspots, the lumber company was found to be at fault.

As with anything else, the more one uses the unit, the better one gets, and the more useful the resulting information becomes. The operator becomes more confident, the interpretation improves and troubleshooting is made easier. For example, the operators of the AVIOSS unit at the BIA office in Billings had a focus problem and were able to isolate it to the focus knob on the Probeye viewer. They finally discovered that the knob got moved each time it was taken in and out of the scanner head. Simply taping the knob in place solved the problem.

FUTURE DEVELOPMENTS

A recent technological development appears to offer great promise in improving the capability of the AVIOSS unit. I'm referring to production of a small LORAN navigational/mapping unit which can be mated to an AVIOSS unit. It gives latitude and longitude in the form of dots, and when used with a computer program setup, can produce a map with certain geographical features and hotspot locations. The LORAN unit is in communication with a ground station, and locations are transmitted every five minutes. Areas and linear distances can also be computed. An individual unit costs around $U.S.10,000. Future additions to the AVIOSS unit include the use of sun filters to extend scanning periods and the ability to transmit IR imagery directly to the fire camp while a scanning mission is in progress.

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AN OVERVIEW OF IAMS: THE INITIAL ATTACK MANAGEMENT SYSTEM

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ABSTRACT

The Initial Attack Management System (IAMS) is a computer based fire management decision support system. The overall goal of IAMS is the reduction of fire suppression costs through the consolidation, distribution and presentation of quality, relevant, and timely information to the local initial attack fire manager throughout the Bureau of Land Management (BLM). To accomplish this goal, IAMS integrates remotely sensed lightning occurrence data from the BLM's Automatic Lightning Detection System (ALDS), meteorological data from the BLM's Remote Automatic Weather Station (RAWS) program, specifically developed and widely available large scale geo-referenced digital data bases and several fire modeling/fire management computer software packages into a comprehensive electronic system. End user information is available through a series of 57 Remote Interactive Graphics Systems (RIGS) placed in most of the bureau's fire management/fire dispatch offices. Utilizing the Initial Attack Management System (IAMS), the local fire manager has at his fingertips, in as close to real time as possible, fire suppression information only dreamed of a few years ago. Proper utilization of this data has great potential for reducing the annual expenditures for wildfire suppression, as well as saving our precious resources.

INTRODUCTION

The Bureau of Land Management (BLM) has wildfire suppression responsibility for over 141.6 million ha of land in the contiguous eleven western states and Alaska. Each year, on an average, wildfires burn over 364 thousand ha of BLM land. In an effort to reduce the annual cost of wildfire suppression, the BLM has developed a program called the Initial Attack Management System (IAMS). The overall goal of IAMS is the reduction of fire suppression costs through the consolidation, distribution and presentation of quality, relevant and timely information to the local initial attack fire manager throughout the Bureau of Land Management.

SYSTEM DEVELOPMENT

Automatic Lightning Detection System (ALDS)

In the early to middle 1970s the BLM was spending vast amounts of money for aerial detection of lightning and lightning caused wildfires within the state of Alaska. Concurrently, research was being conducted in the United States and Canada into lightning and the detection of its occurrence. The BLM, aware of these activities, awarded a research grant to the University of Arizona for the development of an automated electronic system that would detect and plot cloud to ground lightning. The Division of Information Systems Management (then called the Division of Communications) located at the Boise Interagency Fire Center (BIFC) in Boise, Idaho, was charged with the implementation of the system.

Starting with just two electronic sensors (called direction finders or DFs) and temporary radio link, the beginning of an Automatic Lightning Detection System (ALDS) was installed in 1976. This new ALDS system expanded rapidly and grew in sophistication. Within several years, ALDS was providing fire managers throughout the West overwhelming amounts of lightning location information.

Continually changing and expanding, ALDS is currently a very large and technically advanced remote sensing system consisting two geographically separate networks. The "lower 48" network utilizes 33 DFs strategically placed throughout the western U.S., while the Alaskan network consists of 9 DFs maintained by the BLM in Fairbanks, with the monitoring of 3 additional DFs in Canada (Brown 1988). Theoretically, ALDS is capable of detecting up to 99% of all cloud-to-ground lightning that occurs within the contiguous 11 western states (Fig. 1). The 33 DFs comprising the "lower 48" network are tied to BIFC through a complex satellite communications system. It is here

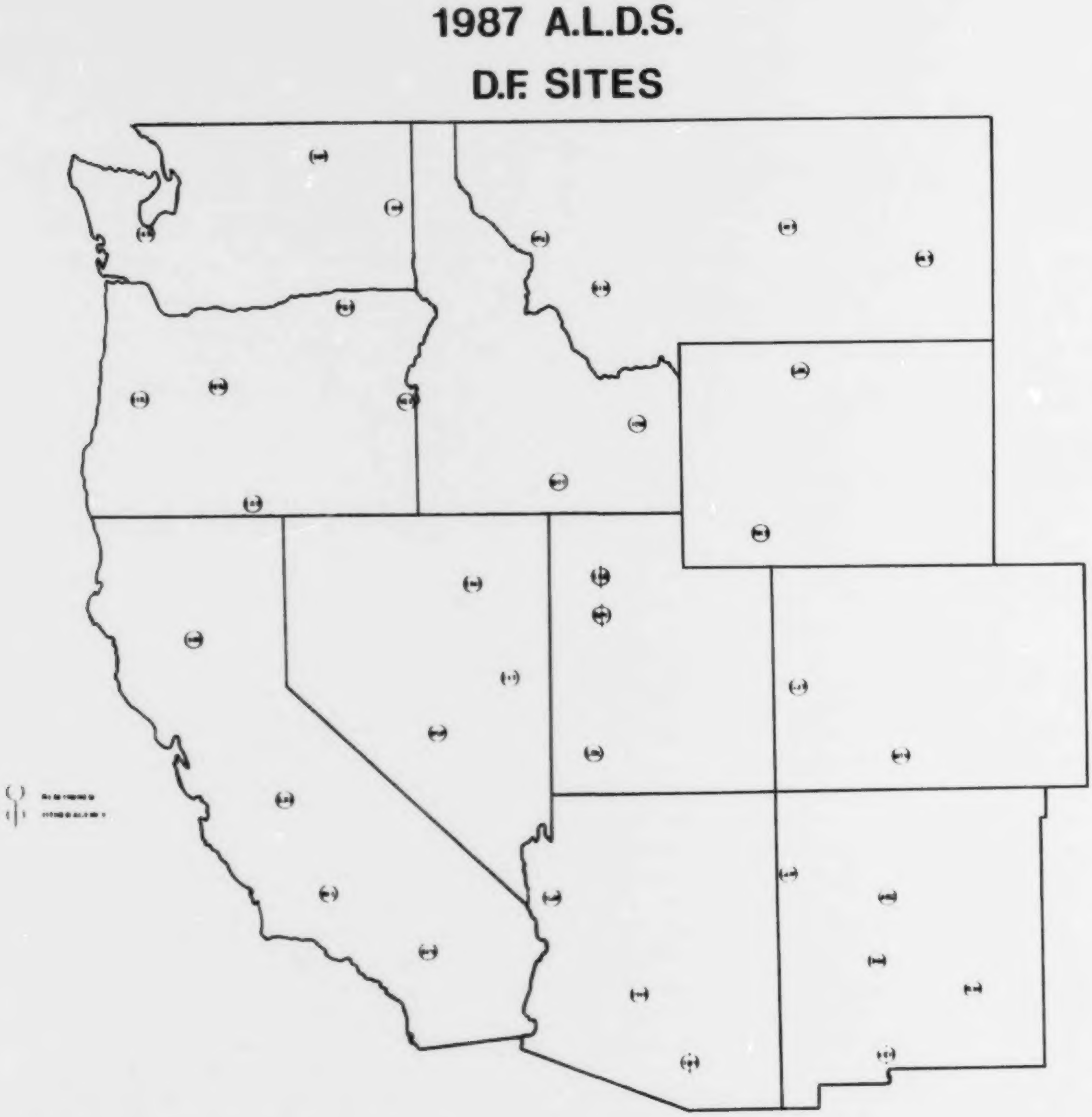

Figure 1. Automatic Lightning Detection System (ALDS) direction finders (DF) sites.

at BIFC that the raw lightning data (angle, time of occurrence, relative signal strength, number of strokes and polarity) is processed within a specialized computer called a position analyzer (PA). Output in the form of a latitude and longitude location is immediately sent to the IAMS central computer system for distribution and archiving.

The output of the bureau's ALDS network is now being sent to the State University of New York (SUNY), where it is providing vital data for developing a national lightning detection system.

Remote Automatic Weather Station (RAWS) System

The ALDS provides fire managers with the information to reduce fire suppression costs by directing them to the highest fire probability areas based on lightning activity. Overwhelmed by the quantity of lightning and acutely aware of the need for additional supporting data, the ALDS field users proposed that even greater savings could be realized if they knew the real-time weather conditions in the area of the lightning activity. This combined data could then provide the fire manager with the facts to respond to the area of highest fire probability due to the lightning activity and the prevailing weather conditions.

In response to the fire community's proposal, the bureau's Remote Automatic Weather Station (RAWS) program was developed. As with ALDS, the RAWS program started small and continued to grow. A joint BLM-U.S. Forest Service team developed the specifications for the RAWS station itself. Commercial station availability was investigated, a system configuration, station classification (Table 1), station configuration by class (Table 2), dispersement plan (Table 3), maintenance methodologies, etc. were all developed shortly afterwards.

Today, close to 200 BLM RAWS stations cover the 11 western states and Alaska. The RAWS stations collect current weather data, summarize it on an hourly basis and then transmit the most recent three hours of data. Capitalizing on the communications capabilities of the geostationary operational environment satellite (GOES) system, a mini-computer controlled satellite receiving station (Direct Readout Ground Station or "DRGS") located at BIFC and a data link directly to the IAMS computer, the data is interfaced into the IAMS system where it is distributed and archived (Fig. 2).

Table 1. RAWS station classifications

Stations will be classified in the following three major classes:

Class I
Those stations comprising the 120.7-km grid network. These units will be permanent, have additional sensor complement, increased sensor capability and have top maintenance priority. These units will be maintained year round.

Class II
Those stations placed by local fire and resource managers. These units will be standard fire weather configuration, semipermanent, and depending upon prevailing fire conditions, will have either primary or secondary priority for maintenance.

Class III
Those stations cached at a central pool available for controlled burns, special studies and additional coverage as required. These units will be placed on a temporary basis and returned to the cache after use. They will have secondary maintenance priority unless otherwise identified.

Note: Emergency situations will be handled accordingly on all field RAWS units, when necessary.

Table 2. RAWS station configuration by class

Class I. Base network—92 fixed stations

A. Fire management requirements

1. Total precipitation (tipping bucket, weighing gauge, or snow pillow)
2. Wind speed
3. Wind direction
4. Air temperature
5. Relative humidity
6. Fuel temperature
7. Battery voltage
8. Barometric pressure
9. Fuel moisture (direct or computed)

B. Sensors under consideration for resource management

Continued on next page

Table 2 continued

1. Soil temperature
2. Soil moisture
3. Weighing gauge precipitation

Class II. Fire weather—174 stations

A. Standard sensor complement
  1. Tipping bucket rain gauge
  2. Wind speed
  3. Wind direction
  4. Air temperature
  5. Relative humidity
  6. Fuel temperature
  7. Battery voltage
  8. Barometric pressure
  9. Fuel moisture (direct or computed)

B. Sensors under consideration for resource management
  1. Soil temperature
  2. Soil moisture (direct)
  3. Weighing gauge precipitation

Class III. Pooled stations—30 stations

Same configuration as Class II.

Table 3. BLM RAWS dispersement by state

State	Dedicated 120-km grid (Class I)	Fire management placed (Class II)
Arizona	5	20
California	9	21
Colorado	3	13
Idaho	6	23
Montana	11	13
Nevada	18	22
New Mexico	8	12
Oregon	10	30
Utah	12	13
Washington	1	
Wyoming	10	7
Subtotals	93	174

There will be an additional 25 Class II stations purchased to compensate for local anomalies not considered in the original study.

There will also be 30 Class III RAWS units cached at BIFC.

Totals	
Class I	92
Class II	199
Class III	30
Spares (10%)	30
Total	351

Upon full implementation of the RAWS program, there will be approximately 350 BLM weather stations in the "lower 48". As a result of interagency coordination and cooperation, there will be close to 600 weather stations in place providing fire and resource managers "real time" weather data through IAMS.

INITIAL ATTACK MANAGEMENT SYSTEM (IAMS)

A review of fire history records showed that 65% of all wildfires within the western U.S. were started by ground stroke lightning. The review further indicated that 70% of all western public lands burned were a result of lightning caused fires. Suppression costs were averaging $10,000 for fires less than 4.04 ha, while the average would escalate to nearly $55,000 for fires 4.04 ha and larger. From these and additional suppression cost figures, it became obvious that a method to effectively and efficiently combine, analyze and present the ALDS and RAWS data was necessary. To solve this need and to provide the necessary additional, and even more complex, fire management programs to the local fire manager, the Initial Attack Management System was formulated.

System specifications soon followed the original concept. The IAMS needed to contain the essential support data upon which every fire management officer depends. Basic data needs include the type of fuels present to burn, terrain information on which the fuels lie, models for predicting the probability of fire start, and fire spread models upon ignition. The IAMS also had to contain a technically advanced delivery system for the information. From this point on, IAMS developed not only into a real time remote sensing system but into a geographic information system (GIS) as well.

Geo-referenced data bases had to be acquired or developed specifically for IAMS. This task was turned over to the Division of Advanced Data Technology, Branch of Remote Sensing, at the BLM's Denver Service Center (DSC). These databases include fire fuels cover class, terrain data (elevation, slope, and

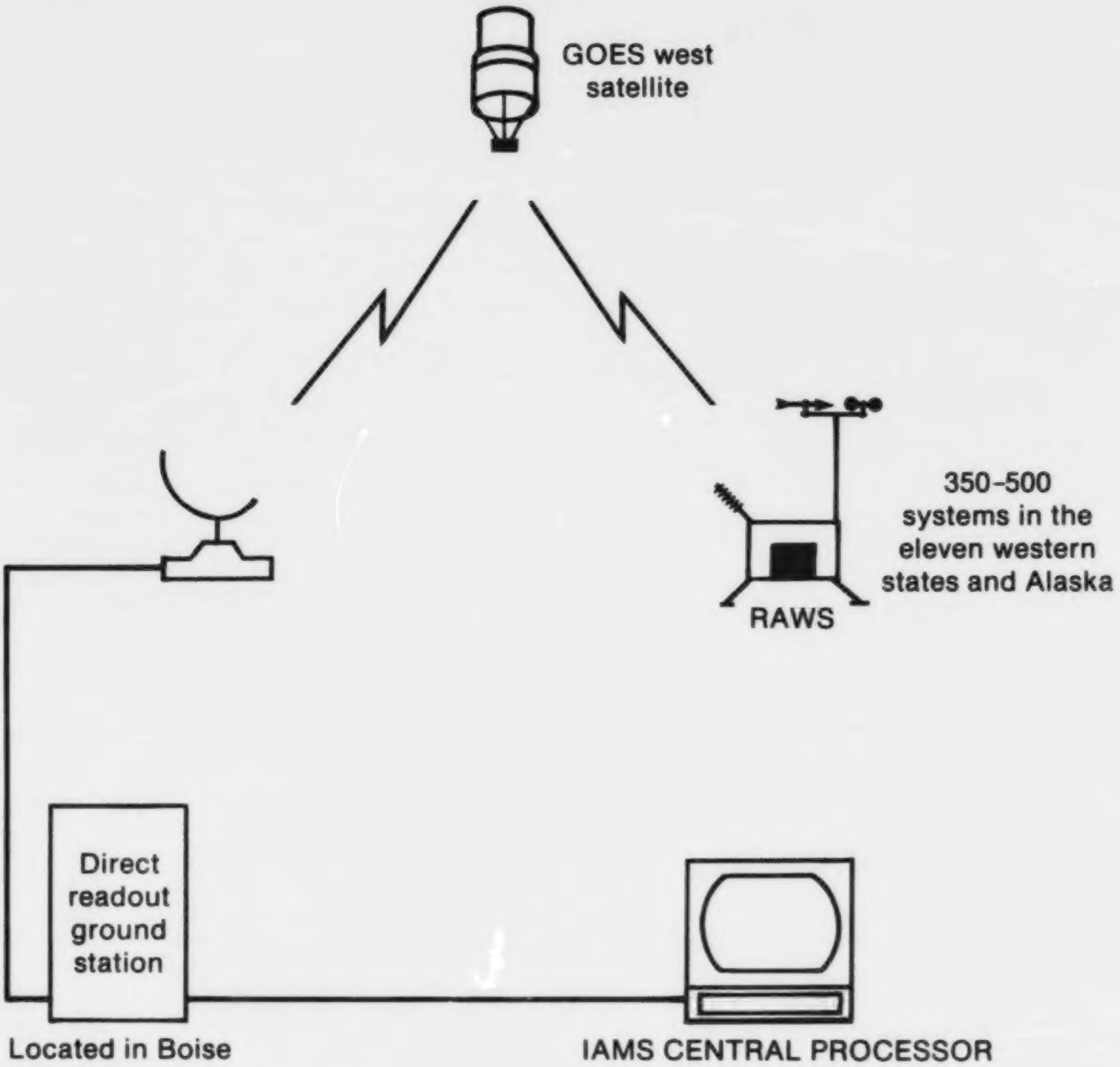
GOES west satellite
350–500 systems in the eleven western states and Alaska
RAWS
Direct readout ground station
Located in Boise
IAMS CENTRAL PROCESSOR

Figure 2. Remote Automatic Weather Station systems configuration.

aspect) and digital line graph (DLG) map data (transportation, hydrology, political and administrative boundaries, landmarks, etc.).

The IAMS fire fuel database was developed using National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) scanner data and contains 34 BLM standard cover classes (Table 4). These classes are an aggregation of vegetation types that have similar fire behavior. The digital data base resident within IAMS consists of approximately 5.4 million 67.1-ha cells covering the 11 western states (Werth, McKinley and Chine 1985). A representative output example of this data base is contained in Figure 3.

In addition to the above databases, IAMS contains several fire management support packages. These include BEHAVE, the U.S. Forest Service's fire behavior software package, customized aircraft tracking programs, an up-to-date electronic mail system and sophisticated mapping display software. An interagency electronic mail interchange with the entire U.S. Forest Service is also available.

Table 4. IAMS standard fire fuel cover classifications, as developed to provide bureau-wide uniformity

1. Grassland
2. Salt desert shrub
3. Mixed desert shrub
4. Black brush
5. Chaparral
6. Sagebrush/grassland
7. Sagebrush
8. Low shrub
9. Sagebrush/pinon-juniper
10. Mountain shrub
11. Dwarf mountain shrub
12. Foothill woodland
13. Pinon-juniper
14. Mixed conifer
15. Lowland conifer
16. Mixed conifer-sparse
17. Mixed conifer-dense
18. Aspen/shrub
19. Subalpine
20. Agriculture/wetland
21. Barren
22. Barren/shrub
23. Water
24. Urban
25. Black spruce/feather moss
26. Tussock
27. White spruce
28. Hardwood/mixed forest
29. Nonburnable
30. Forest brush
31. Juniper
32. Logging slash
33. Alpine meadow
34. Open pinyon-juniper

All of the above information is available through a bureau-wide graphics computer network (Fig. 4). Each of the 57 Remote Interactive Graphics System (RIGS) contains specific map and other local data bases necessary for that office's area of responsibility. Through the ALDS/IAMS satellite communications system (Fig. 5), the RIGS provide a dedicated path to all the models and data within the central system in Boise.

CONCLUSION

The IAMS is a state of the art multifaceted system. It utilizes the most modern technology in the fields of electronics, data communications, remote sensing, and computer science. It delivers a wealth of information into the hands of those directly responsible for fire suppression within the Bureau of Land Management and other cooperative fire organizations. Proper utilization of this data has great potential for reducing the annual expenditures for wildfire suppression, as well as saving our precious resources.

ACKNOWLEDGMENTS

The author gratefully acknowledges Lonnie Brown, the Automatic Lightning Detection System program manager of BLM's Boise Interagency Fire Center for information, as well as for providing figures 1, 4, and 5. The author also acknowledges Phil Sielaff, the Remote Automatic Weather Station program manager, for providing Figure 2 and tables 1, 2, and 3.

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                           Fire Fuels report
           118:31                   118:30                    118:29
        :-------------:-------------:-------------:-------------:-------------
fuel    : Sagebrush   : Sagebrush   : Salt Desert : Sagebrush   : Sagebrush   :
        : Grassland   : Grassland   : Shrub       : Grassland   : Grassland   :
        :             :             :             :             :             :
elev    : 5601 - 6400 : 5601 - 6400 : 5601 - 6400 : 6401 - 7200 : 7201 - 9000 :
slope   :   40 - UP   :   40 - UP   :   40 - UP   :   40 - UP   :   40 - UP   :
aspect  :  Northwest  :  Northwest  :  Northwest  :  Northwest  :  Northwest  :
        :-------------:-------------:-------------:-------------:-------------:
fuel    : Salt Desert : Salt Desert : Salt Desert : Sagebrush   : Sagebrush   :
        : Shrub       : Shrub       : Shrub       : Grassland   : Grassland   :
41:20   :             :             :             :             :             :
elev    : 4801 - 5600 : 5601 - 6400 : 5601 - 6400 : 6401 - 7200 : 6401 - 7200 :
slope   :   40 - UP   :   40 - UP   :   40 - UP   :   40 - UP   :   40 - UP   :
aspect  :  Southwest  :  Southwest  :  Southwest  :  Southwest  :  Southwest  :
        :-------------:-------------:-------------:-------------:-------------:
fuel    : Salt Desert : Salt Desert : Salt Desert : Agriculture : Agriculture :
        : Shrub       : Shrub       : Shrub       : Wetland     : Wetland     :
        :             :             :             :             :             :
elev    : 4001 - 4800 : 4801 - 5600 : 4801 - 5600 : 5601 - 6400 : 5601 - 6400 :
slope   :   20 - 40   :   40 - UP   :   40 - UP   :   40 - UP   :   40 - UP   :
aspect  :  Southwest  :  Southwest  :  Southwest  :  Southwest  :  Southwest  :
        :-------------:-------------:-------------:-------------:-------------:
fuel    : Sagebrush   : Salt Desert : Salt Desert : Sagebrush   : Sagebrush   :
        : Grassland   : Shrub       : Shrub       : Grassland   : Grassland   :
41:19   :             :             :             :             :             :
elev    : 4801 - 5600 : 5601 - 6400 : 4801 - 5600 : 4801 - 5600 : 5601 - 6400 :
slope   :   40 - UP   :   20 - 40   :   20 - 40   :   20 - 40   :   40 - UP   :
aspect  :  Northeast  :  Northeast  :  Northeast  :  Southwest  :  Southwest  :
        :-------------:-------------:-------------:-------------:-------------:
fuel    : Salt Desert : Salt Desert : Salt Desert : Sagebrush   : Sagebrush   :
        : Shrub       : Shrub       : Shrub       : Grassland   : Grassland   :
        :             :             :             :             :             :
elev    : 5601 - 6400 : 5601 - 6400 : 5601 - 6400 : 4801 - 5600 : 4801 - 5600 :
slope   :   20 - 40   :   40 - UP   :   40 - UP   :   20 - 40   :   20 - 40   :
aspect  :  Northeast  :  Northeast  :  Northeast  :  Northeast  :  Southwest  :
        :-------------:-------------:-------------:-------------:-------------
           118:31                   118:30                    118:29
```

Figure 3. Bureau of Land Management Initial Attack Management System.

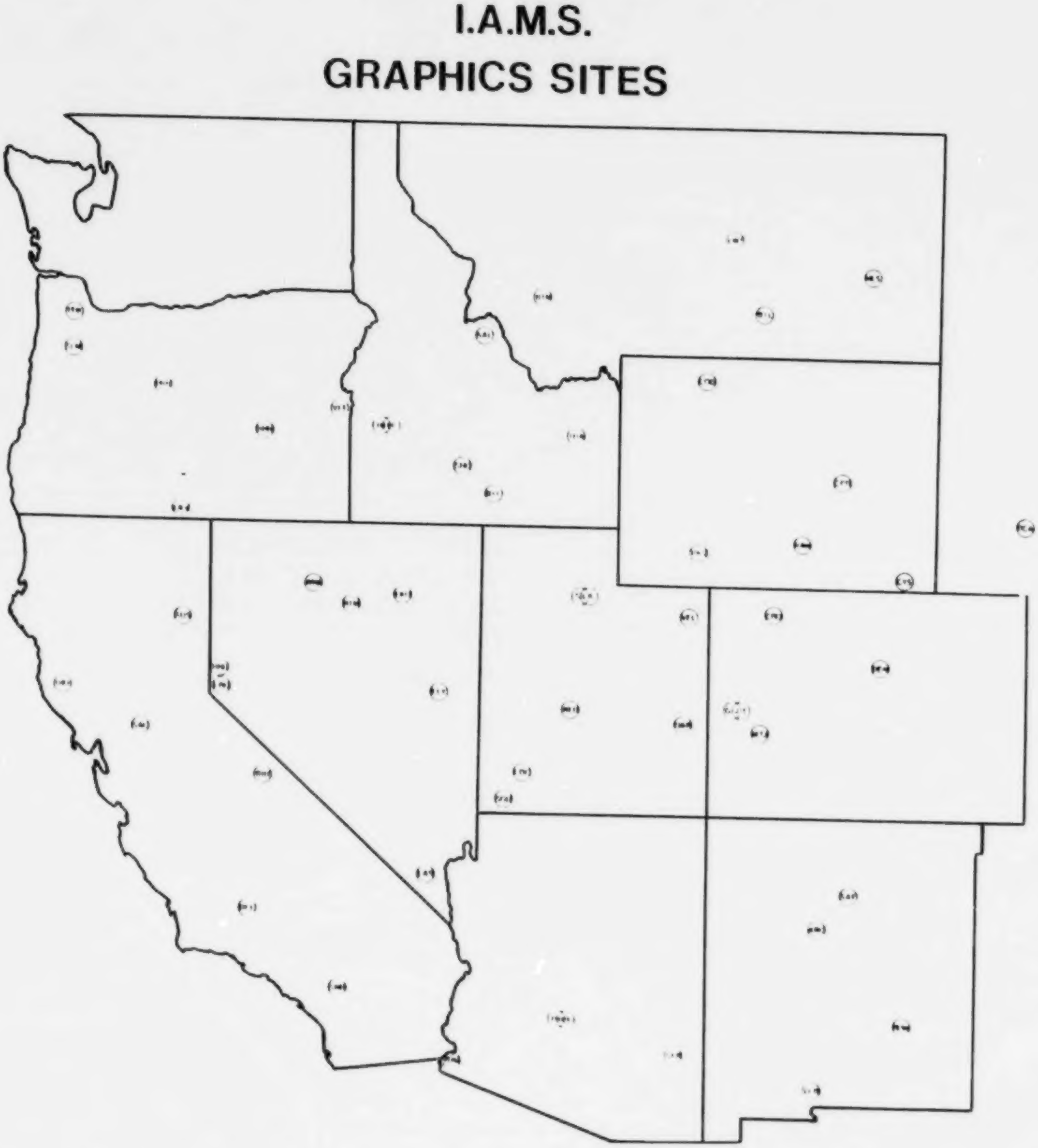
I.A.M.S.
GRAPHICS SITES

Figure 4. The Initial Attack Management System graphics sites.

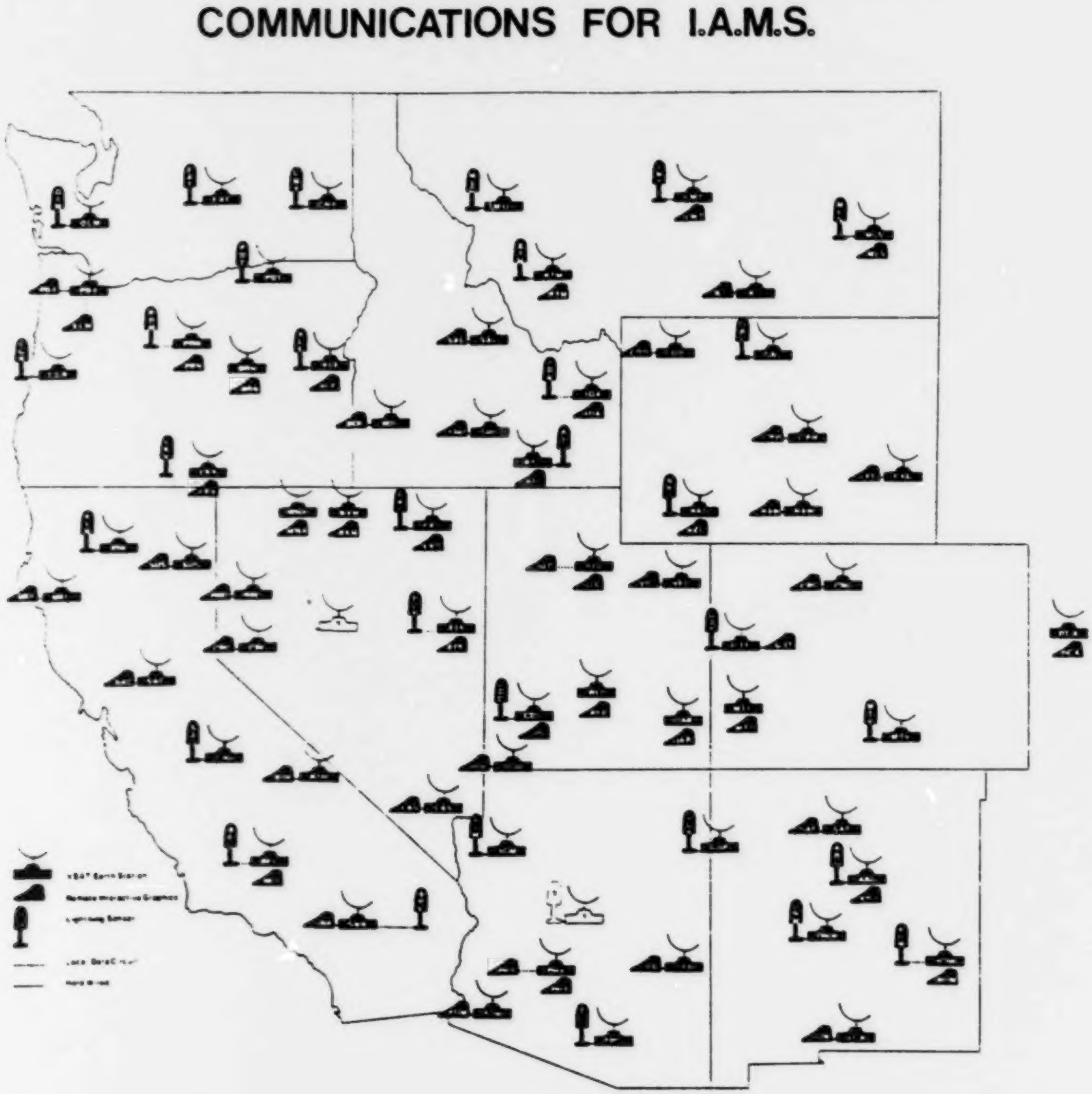
COMMUNICATIONS FOR I.A.M.S.
VSAT Earth Station
Remote Interactive Graphics
Lightning Sensor
Local Data Circuit
Hard Wired

Figure 5. Communications for IAMS.

ALBERTA'S SYSTEM FOR DETERMINING FIRE PROTECTION PRIORITIES

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ABSTRACT

This paper will show the progression of efforts made by the Alberta Forest Service (AFS) in developing guidelines for forest fire suppression that are in concert with human and forest resource values. A method for determining resource fire protection priorities was developed in 1985 by a task force from within the AFS fire management group. The method utilizes existing AFS data bases and is subject to interpretation by fire management staff. The forest protection area of the province is broken down into individual areas varying in size from a section (259 ha) to a township (9331 ha), and each area is assessed assuming all lands are managed for multiple use. All forest resource values plus the protection of people and real personal property from wildfire are considered and assigned points from a simple rating scheme. Prime protection areas are identified over and above the rating scheme for population centers, major developments, and certain land units of special status such as prime habitat areas supporting endangered species. Forest resource value items include timber, recreation, watershed, wildlife, soil sensitivity, and minor developments. The system is intended to be used as a tool in conjunction with other components used to make fire management decisions. This system is the first step in developing a future priority map that will require detailed input from resource and land managers to refine priorities and correct any bias that may have developed during the initial preparation of the system.

INTRODUCTION

For many years, fire management agencies have endeavored to carry out protection efforts in a priority manner. In Alberta, prior to 1976, this consisted of local fire managers using personal knowledge and experience blended with direction from provincial headquarters. With the advent of air tanker support in wildfire suppression, Carson McDonald, then Head of Fire Operations with the Alberta Forest Service (AFS), developed a priority system (McDonald 1976). This report recognized four priorities:

1. Population areas.
2. Major watershed and recreation areas, including merchantable coniferous timber volumes (greater than 3000 foot board measure (fbm) per acre).
3. Active oil and gas fields, and timber management units containing merchantable coniferous timber volumes (greater than 3000 fbm per acre).
4. Important grazing areas and potentially productive/low volume timber management areas (less than 3000 fbm per acre).

This report included two maps that were combined to create a third map called the Fire Suppression Priorities Map. The first map took into account five land uses: populated areas, major watershed value areas, active oil and gas fields, active woods operations, and active grazing areas. These considerations were then depicted in one of six categories ranging from populated areas to those areas affected by four or five of the considerations, to areas affected by none of the considerations. The second map simply showed the coniferous timber resources of that time. This system pioneered suppression priority efforts in Alberta.

The 1979-82 fire seasons in Alberta were record years in terms of fire incidence, area burned, and suppression expenditures (Gray and Janz 1985). Alberta's review of these record years led to the conclusion that the capabilities of the protection agency in presuppression activities needed to be strengthened. Thus, a new strategy termed the Presuppression Preparedness Resource System (PPRS) was developed, tested, and implemented (Gray and Janz 1985). Following implementation of the PPRS, it was recognized that suppression resource distribution must coincide with resource values now evident and appreciated across the province. Thus, in December 1984, the fire management group within AFS appointed a task force that was established to address the issue of resource priorities from a fire protection standpoint[1]. The primary objective of the task force was the development of a simple yet workable model based on readily available data within the AFS for determining resource protection priorities on an interim basis. At the outset, the task force concluded that cost-effective planning must consider three types of fire management decisions requiring consideration of values-at-risk:

1. The *political* decisions involve determining the level of fire management expenditure for a fire control agency. Decisions are based on resource allocation and use commitments made by government.

2. The *administrative* decisions involve distributing fire control funds among the 10 forests and fire-related activities of the AFS Forest Protection Branch. These decisions address the question: Given an overall level of fire management expenditure, how, where, and when should the money be split?

3. The *operational* decisions involve preparing for and dealing with wildfire; the daily resource readiness, dispatch, and suppression decisions. These decisions use values-at-risk when difficult trade-offs must be made. The more difficult the trade-off, the more important values-at-risk knowledge becomes.

In January 1985, the task force completed a report[2] that presented a procedure to quantify and determine resource values under forest fire protection on a province-wide basis to allow sound fire management decision making consistent with values-at-risk.

SYSTEM ELEMENTS

The approach taken is based on determination of relative index values for unit area cells within the forest protection area of Alberta. This approach satisfies the requirements of being simple, workable, and dependent on readily available data within the AFS. The main elements of the system include 1) the resource appraisal unit, 2) resource values under consideration, 3) resource value scale, and 4) the fire protection priority scale. These elements are discussed in more detail in the remainder of this section.

Resource Appraisal Unit

The basis for measurement of fire protection priorities are unit area cells. It is assumed that all lands are managed for multiple use. Cell size options include townships (9331 ha), quarter townships (2333 ha) and sections (259 ha). The township should be the largest cell area with respect to assessment of fire protection priorities. The fire protection priorities system provides an index of the total protected values of a particular cell. Once cell indexes are determined, cells can be ranked according to protection priorities. For higher resolution analysis, cells with a high value index can be dissected into smaller areas to more accurately assess protection requirements. This process also helps to identify candidate areas for preattack planning or fuels management programs.

Resource Values Under Consideration

Forests contain widely different combinations of vegetation, animals, soil, climate, configuration, and ecological interactions. Forests are valuable because they serve various human, social, and economic needs. Value is derived from the supply of products and services and the demand for them. Values-at-risk indicate that any or all of the useful natural resources can be jeopardized when a fire occurs. It follows that forest fire control is carried out to permit the achievement of certain social and economic resource-related goals. "Value protected" is conceived here to include only the resource value subject to fire damage. It is recognized that certain resources are affected to a lesser degree by fire than others. In fact, some resources may be enhanced by fire.

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[1] Task force members at that time included William M. Wuth, (Forest Protection Officer, Grande Prairie Forest), James M. Skrenek (Manager-Fire Management Program, Forest Protection Branch, Edmonton), and Edwin R. Johnson (Forest Protection Officer, Whitecourt Forest) as chairman.

[2] Alberta Forest Service. 1985. A method for determining resource fire protection priorities. Alberta Forest Service. For. Prot. Branch, Edmonton, Alberta. Unpubl. Rep.

Resource values-at-risk form two basic groups: 1) nonforest resource values, i.e., people and real or personal property, and 2) forest resource values, i.e., values derived from forest resources and forest products. The resource group includes timber, watershed, recreation, wildlife, and soil. The nonforest group includes values such as human life, health, physical and economic well being, and real and personal property.

Resource Value Scale

Each resource at risk is affected to a different degree by wildfire; each resource also has a different value placed on it by society. In order to arrive at a representative "cell" resource value, the evaluation must be based on the actual quantifiable resource "make-up" in each cell, based on individual resource importance and the corresponding effect if impacted by wildfire.

Based on the perceived relative resource importance and the degree of susceptibility to wildfire, a resource value scale was developed by the resource priorities task force. Table 1 indicates the assigned maximum index value for individual resource components.

Fire Protection Priority Scale

Individual cells evaluated with the fire protection priorities are described by two separate priority-level indicators. The first priority-level indicator provides a measure of the nature of human-valued resource components at risk in the cell. The second priority-level indicator provides a measure of the priority level of the cell based on the aggregate resource value index score for forest resource-valued components. These priority levels are indicated in Table 2. Prime protection areas (e.g., population centers, major man-made developments) are specifically identified on the resource priority base map.

A brief description of the six forest resource values items is given below.

Timber

Forest cover is the single most-valued resource both for the direct benefit of its wood fiber from an economic point of view and also its importance for the existence and quality of other forest resources. Direct loss by wildfire adversely affects all other resources, some to a larger degree than others.

Table 1. Maximum cell value for individual value components in the fire protection priorities system

Resource component	Maximum cell value (points)
Timber	10
Recreation	5
Watershed	2
Wildlife	1
Soil sensitivity	1
Minor developments	1
Total	20

Table 2. Priority levels for human-valued and orest resource-valued items in the fire protection priorities system

Category	Protection level
Human-valued items (prime protection)	
Population centers	Priority 1
Major industrial and commercial developments	Priority 2
Areas requiring special protection recognition	Priority 3
Forest resource-valued items (aggregate cell index value)	
15.1-20.0 points	Priority 1
10.1-15.0 points	Priority 2
5.1-10.0 points	Priority 3
0.0- 5.0 points	Priority 4

Water

Watershed has value owing to its ability to regulate the rate, timing, and quality of water delivered to stream flow and storage and its ability to regulate soil erosion. Wildfires can cause changes in watershed performance and have an impact on people and other resource capabilities. Watersheds vary in importance, and the effects of fire vary greatly. Losses are noticeable in the short term, but in relation to mature timber resources they "heal" relatively sooner.

Wildlife

Wildfire damage may reduce the opportunity for people to participate in wildlife use and enjoyment; however, the current demand for opportunity must be considered. Another possible wildfire impact is habitat destruction and the cost to restore both the habitat and the wildlife population. In some cases fire effects on wildlife habitat are beneficial, but a large, intense wildfire would normally create serious habitat and physical resource destruction. Both beneficial and harmful effects of wildfire are recognized.

Recreation

Outdoor recreation is a resource that places demands on wildland managers equal to or exceeding those of timber, water, forage, or wildlife. This demand varies with location and amount of recreational experiences at risk.

Soil Sensitivity

Fire has a direct and indirect effect on soil. Fire intensity is of course a key element. The value attached to soil sensitivity is in consideration of its potential erodability following fire. Effects will be significant in unstable soil conditions and have little impact on stable soils.

Minor Developments

Minor developments encompass land surface developments such as remote residential areas or light oil field developments of a fixed nature (i.e., satellites, batteries, producing wells, microwave stations). The effect of fire on these resources is varied depending on the type of development and location. Consequently, the significance attached to these resources is low in comparison to the other forest resource value items.

SYSTEM PROCEDURES

Priority levels associated with particular cells are determined using the resource value priority worksheet (Fig. 1). The first step in assigning a priority to a cell is to define the location of the cell. Cell location is based on legal land description. The worksheet has three parts. The procedure for each part is described in the following sections. A completed worksheet for a sample cell area is shown in Figure 1, and a corresponding enlargement of the same map area is given in Figure 2.

Part I: Prime Protection

This portion of the worksheet considers human-valued items that require prime protection. These are specifically identified on the base map prior to determining priority levels. Population centers include all communities, cities, towns, villages, hamlets, settlements, cottage developments, resorts, subdivisions, campgrounds, and provincial parks. Major industrial and commercial facilities (e.g., sawmills, gas plants, and other types of infrastructure) are also included. Unique areas requiring special protection recognition include habitat areas supporting endangered species of either flora and fauna areas where wildfire is considered detrimental and areas where soil sensitivity or watershed values require special status.

Part II: Sample Cell Resource Value Weighing

Section A. Timber Resources

Timber resource value is based upon its quantity, quality, and location. The maximum value a cell can receive is 10. Numerical values are determined by visually determining the proportion of area that specific timber classes account for on the total cell and multiplying it by the weight assigned to the individual timber resource. The section total is the summation of the individual timber values.

1. Committed merchantable timber includes all stands identified for cutting during the next 20 years (i.e., Forest Management Agreement areas, quota licenses, quota certificates, community wood lots, and tree farms).

RESOURCE VALUE PRIORITY WORKSHEET

CELL LOCATION (....NW 61-12-5....................)

PART I PRIME PROTECTION (Human Valued Concerns)

1. Population Centres ______
2. Major Industrial & Commercial Developments ______
3. Specific Areas Requiring Special Protection Recognition ______

PART II SAMPLE CELL RESOURCE VALUE WEIGHTING

Section A. Timber Resource

1. Committed Merchantable Timber ...%of cell...x10/100 =...10.
2. Non-committed Merchantable Timber
   - a) economical @ present ...%of cell...x 8/100 =....
   - b) not economical @ present ...%of cell...x 5/100 =....
3. Growing Stock Merchantable in 50 years ...%of cell...x 5/100 =....
4. Potential Productive Lands ...%of cell...x 3/100 =....
5. Non-productive Lands ...%of cell...x 1/100 =....
6. Intensive Silviculture Areas ...%of cell...x 2/100 =....

Section Total..... 10

Section B. Watershed

1. Primary - Specify Drainage................ = (2)
2. Secondary - Specify Drainage.............. = (1)
3. Limited.................................... = (0)

Section Total..... 0

Section C. Recreation Potential

Quantity Level		Need Level
1. High ...5 (6-9 activities)		Immediate (1)
2. Medium..3 (3-5 activities)	x	Within 10 yrs (.5)=
3. Low ....1 (1-2 activities)		After 10 yrs (.25)
4. Nil.....0 (Insign. Potential)		

Section Total..... 3

Section D. Wildlife

1. Normal Habitat (1)

Section Total..... 1

Section E. Soil Sensitivity

1. Unstable Terrain (1)
2. Stable Terrain (0)

Section Total..... 0

Section F. Minor Developments

1. Existing (1)
2. Non-existing (0)

Section Total..... 1

PART III SAMPLE CELL SUMMARY

Section A. Initial Total Cell Points 16

Section B. Sample Cell Priority Level

1. Priority 1 = 15.1 to 20 cell points
2. Priority 2 = 10.1 to 15 cell points
3. Priority 3 = 5.1 to 10 cell points
4. Priority 4 - 0 to 5 cell points

** Note Caution

Section C. Adjusted Cell Points 16

Section D. Sample Cell Priority Level .... [✓ 1]; 2; 3; 4

Section E. Prime Protection Identification............. 1; 2; 3

Figure 1. Sample of a resource value priority worksheet.

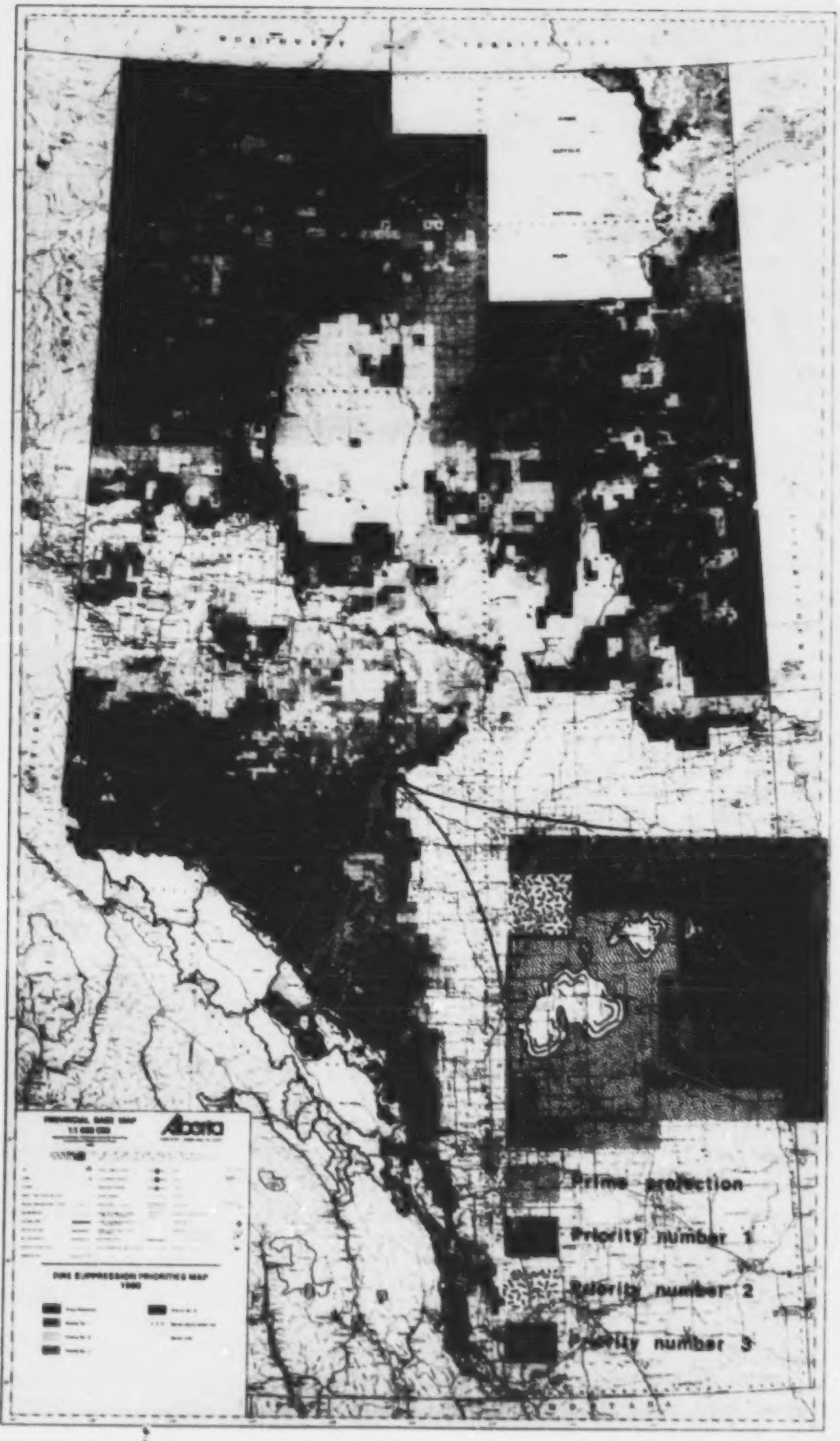
Alberta
Prime protection
Priority number 1
Priority number 2
Priority number 3

Figure 2. Fire suppression priorities map, 1988.

2. Noncommitted merchantable timber includes 1) currently economically accessible but not committed timber, and 2) economically inaccessible timber.

3. Growing stock includes stocked areas containing growing stock that will be merchantable within a 50-year period.

4. Potentially productive areas include lands that do not possess an established forest crop but have potential for growing merchantable stands.

5. Nonproductive lands include areas incapable of supporting a commercial timber crop (e.g., bogs, marsh, muskeg). These lands do have other values that could be negated by wildfire.

6. Intensive silviculture areas include lands that have undergone some form of intensive management, resulting in enhanced production (i.e., plantations, thinning sites, provenance trails, experimental areas).

Section B. Watershed

Three priority levels for watersheds are identified on the worksheet. The head of major rivers such as the Saskatchewan watershed is of primary downstream importance with respect to potential fire effects, and these areas are assigned a priority index value of 2.0. Secondary and minor rivers such as the watershed supporting the Lac La Biche River are affected to a lesser degree by wildfire in terms of water quality and retention flow and are therefore assigned a value of 1.0. All remaining areas are assigned a 0.0 value.

Section C. Recreation Potential

Developed recreation facilities are considered in Part I of the evaluation worksheet. This section considers the impact of wildfire on dispersed recreation activities and on areas that have potential for development of recreation facilities. Those recreation activities considered to be negatively affected by wildfire include trail riding, skiing (cross country and downhill) snowmobiling, hiking, photography, picnicking (day use), camping, cottage development, and boating (canoeing). The recreation potential index is a function of two indicators: the "quantity level" and the "need level." To determine the recreation quantity potential of a cell the number of specific recreation activities available in the cell for future developments are counted. If the cell has six to nine activities it receives a high quantity level (i.e., 5.0). Alternatively, if the area contains one or two of the activities, it receives a low quantity level to determine the recreation potential index. Need level is the analyst's perception of when society will require the particular activities. If the demand is immediate, the need level is classed as 1.0. If demand for the activities will not be apparent for the next 15 years the need level is 0.25. The value of the recreation potential index is then determined by multiplying the quantity level by the need level.

Section D. Wildlife

If a cell provides suitable assigned habitat for wildlife, a value of 1.0 is assigned. Otherwise, a 0.0 value is assigned.

Section E. Soil Sensitivity

If, in the view of the analyst, the terrain of a particular cell is of such a nature that wildfire would contribute to significant erosion problems, an index value of 1.0 is assigned.

Section F. Minor Developments

Minor developments include isolated surface land developments (e.g., oil wells, pumping stations, oil field batteries, microwave towers, remote residential areas). If these developments exist in a cell, a value of 1.0 is assigned; otherwise a 0.0 value is assigned.

Part III: Sample Cell Summary

Part III of the resource value priority worksheet compiles and adjusts the information provided in Parts I and II. The first step in Part III involves determination of the aggregate index value of all forest resource-valued components. The aggregate index value is then used to derive the priority level of the cell (Table 2). If, however, the aggregate index value is at the upper end of the priority class, an adjustment in the priority level may be invoked. In this case a reexamination of the index value assigned to the timber resource is required. If timber was assigned a value greater than 5.0, the priority level of the cell is increased by one. The final step is identification of II human-valued concerns within the cell. This is achieved by selecting any combination of the three prime protection elements.

CONCLUSIONS

The fire protection priority system has been employed to define protection priorities for the Green Area of Alberta. The end result is the *Fire Suppression Priorities Map, 1988* (Fig. 2). Note that the white areas include agriculture lands and national parks. The inset in Figure 2 demonstrates how the system can be used for decisions requiring a higher resolution of analysis. The *Fire Suppression Priorities Map* provides a provincial-level view of the relative values-at-risk in the protected area. The information will lead to more-informed decision making with regard to the political, administrative, and operational decisions that concern fire management.

The *Fire Suppression Priorities Map*, however, is only one small portion of the information base supporting fire management decision making. Other information requirements include fuel type classification and mapping, daily fire danger rating calculations, status of initial attack and other fire control resources, fire weather forecasts, and fire occurrence predictions.

As previously described, the fire protection priorities system was developed based on forest- and district-level input, and it reflects the perspective of fire managers on a provincial basis. The AFS Forest Protection Branch, however, recognizes that the system is an initial step. More-detailed information from resource and land managers is required to refine the indexes and provide more confidence in the indicated priorities. Additional potential refinements to the system include the following:

1. incorporation of fuel-type classification and mapping (currently under development);
2. recognition and incorporation of the latest technological developments such as satellite imagery (e.g., to detect areas of stressed vegetation) and geographic information systems; and
3. recognition of changing resource priorities resulting from societal needs and technological developments (e.g., aspen utilization).

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COMPUTER SIMULATION OF FIRE EFFECTS ON FOREST AND RANGELAND RESOURCES: FIRELAMP IN RETROSPECT

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ABSTRACT

FIRELAMP represents an ambitious, prototype attempt at integrating fire and land management planning, initiated by the USDA Forest Service's Intermountain Research Station and faculty and students at Colorado State University. The model uses existing knowledge about fire simulation, focusing on timber, forage, water, wildlife, and recreation effects over an extended time horizon. This paper provides an overview of FIRELAMP, and outlines its strengths and weaknesses. Also considered are changes that have occurred in fire management decision environments since completion of the prototype. FIRELAMP's strengths include the insights provided by linking a management interface with best available knowledge of fire behavior and danger and fire effects on resource outputs. Knowledge gaps persist to date about the effects of fire on individual organisms and at the ecosystem level of organization. Advances in computing resources and decision capabilities into the 1990s should enhance future efforts. Even so, FIRELAMP represents a unique landmark in our quest to more fully integrate the role of fire in resource management planning efforts.

INTRODUCTION

Our objective today is to provide you with a retrospective look at an ambitious computer prototype developed at Colorado State University (CSU) during the late 1970s. The model was designed to provide short- and long-term perspectives on fire effects over a large planning area. With the benefit of hindsight we will describe the motivation for our efforts, provide an overview of the system, and reflect on the strengths and weaknesses of what we accomplished.

Before doing this, we'd like you to join us on a brief journey back in time to the 1960s and early 1970s. There are many legacies from that time period, but prominent among our memories are concerns for the environment and the need for land management planning. By the late 1970s we had ushered in a new era in fire research in the U.S. with Rothermel's (1972) fire model and improved updates to the U.S. National Fire Danger Rating System (Deeming et al. 1977). Concurrently, the U.S. Forest Service had revised its fire policy to allow integration of fire control and use with land management objectives. Ebullient with successes in the fire behavior and fire danger arenas, and enthused with the mandates of the revised fire policy, the fire in multiple use management research, development, and applications (RD & A) program was initiated at the Intermountain Fire Science Laboratory (formerly the Northern Forest Fire Laboratory) in Missoula, Montana. Its mission included a charge to develop a prototype model that would simulate and display fire effects in a meaningful way for fire and land management planners. Early on, Missoula fire lab principals (Jim Lotan and Dick Barney, among others) recognized the need for an interdisciplinary approach to this effort and contacted the College of Forestry and Natural Resources at CSU about the feasibility of developing this model as a cooperative effort.

Thus, FIRELAMP was conceived, a prototype tool for integrating fire and land management planning.

Freeman Smith and Jack Barrows were coprincipal investigators for the FIRELAMP project. The study team consisted of at least one faculty representative and graduate student from each of the five departments in the college, plus one research associate (Mike Vevea) who kept us in line and talking to each other.

Over the span of about 4 years, we grappled with the task of developing FIRELAMP and installing the code on the CYBER mainframe computer at CSU. Subsequently, FIRELAMP was installed on the PRIME minicomputer at the Missoula fire lab; all the graduate students finished their theses and moved onto bigger and better things—well, at least we hope they are involved with better things. No one will probably ever talk them into becoming involved in a bigger, more ambitious project!

DESCRIPTION OF FIRELAMP

Figure 1 provides a simplified overview of the FIRELAMP system, showing information flows between subsystems. Information about fire activity (ignitions and fire characteristics, driven by a weather simulator) derived in the FIRE subsystem passes to the TIMBER and FORAGE subsystems, which in turn affect the WILDLIFE, WATER, and RECREATION subsystems. These fire effects are simulated over a user-specified time frame (daily, monthly, annually), for eventual display and interpretation at the MANAGEMENT INTERFACE, thus allowing the manager to review and revise the functioning of the model. Though driven primarily by fire events and vegetation changes, the state of the system was also driven by the weather simulator. For example, rainfall and erosion events could be triggered within the ABIOTIC subsystem (and thereby affect the WATER subsystem), quite independently of fire episodes.

Inputs included those necessary to predict fire activity, timber injury and mortality, regeneration and growth, forage and browse production, big game and domestic livestock numbers, water and sediment yield, and recreation opportunities for a large planning unit (80 000-160 000 ha). Also required were statements from planning and resource specialists concerning problem definition, management objectives, and criteria for assessing model performance.

Information passed among and within subsystems may be quite involved and complicated. For example, Figure 2 shows a schematic of the information that was estimated and transferred among the FIRE, TIMBER, and FORAGE subsystems. Fire could occur according to historic fire records or could be controlled through the management interface. Once ignited, the fire's behavior was controlled by fuels, weather, and topography. Fuel characteristics were determined by the stylized fuel models of the U.S. National Fire Danger Rating System (NFDRS); weather variables were randomly generated to represent the area being studied. Fire characteristics were inferred from NFDRS indexes. These in turn directly affected timber and forage production as well as future weather conditions simulated in the ABIOTIC subsystem.

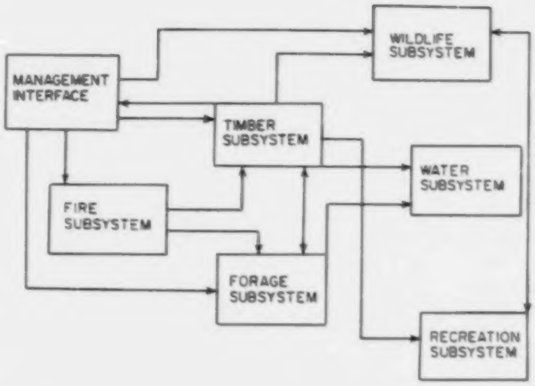

Figure 1. A simplified overview of information flows in the FIRELAMP simulation model.

We developed the model using resource data from the Boulder-Estes Ranger District of the Arapaho-Roosevelt national forests in north-central Colorado. Outputs included tables and graphical displays of different management regimes and their impacts on resource production for eight capability areas (vegetation types) over an extended time horizon (up to 200 years). Output was available over time periods consisting of daily, monthly, and annual time steps. Several example regimes were tested including 1) control (no timber harvest, no thinning, no prescribed fire); 2) prescribed fire treatments (at intervals suggested by forest personnel); and 3) timber harvesting and thinning substituted for prescribed fire.

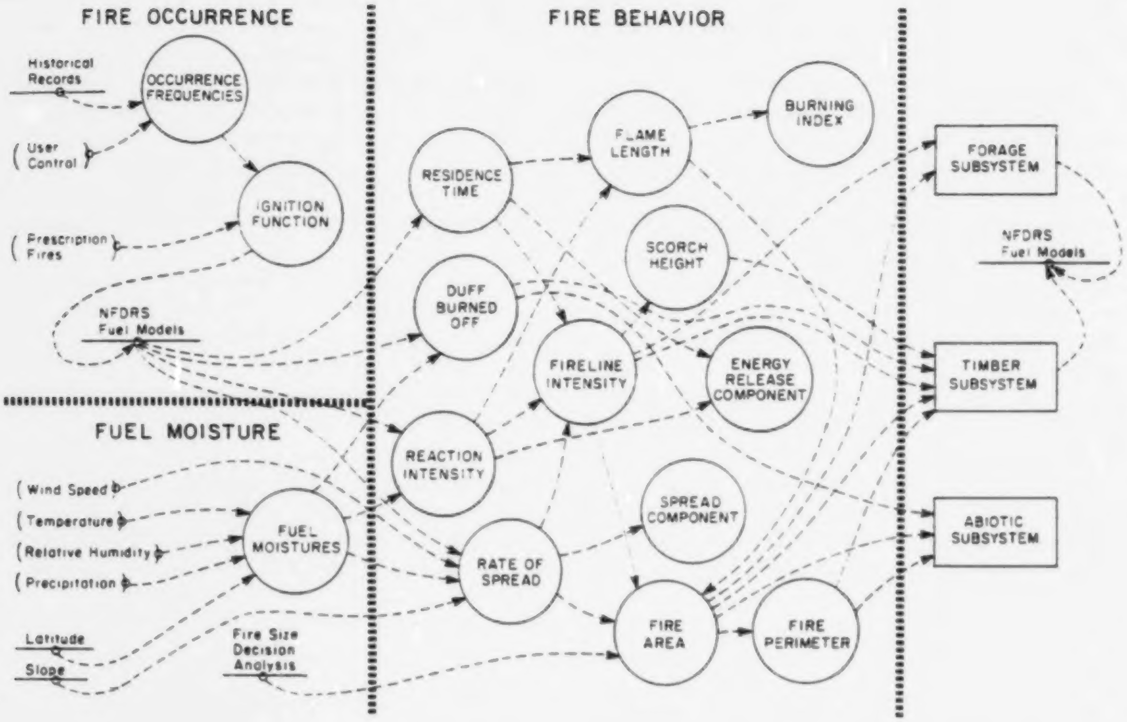
FIRE OCCURRENCE
FIRE BEHAVIOR
Historical Records
OCCURRENCE FREQUENCIES
User Control
IGNITION FUNCTION
Prescription Fires
NFDRS Fuel Models
FUEL MOISTURE
Wind Speed
Temperature
Relative Humidity
Precipitation
FUEL MOISTURES
Latitude
Slope
Fire Size Decision Analysis
RESIDENCE TIME
DUFF BURNED OFF
REACTION INTENSITY
RATE OF SPREAD
FLAME LENGTH
BURNING INDEX
SCORCH HEIGHT
FIRELINE INTENSITY
ENERGY RELEASE COMPONENT
SPREAD COMPONENT
FIRE AREA
FIRE PERIMETER
FORAGE SUBSYSTEM
NFDRS Fuel Models
TIMBER SUBSYSTEM
ABIOTIC SUBSYSTEM

Figure 2. Schematic of fire information derived and transferred to the TIMBER, FORAGE, and ABIOTIC subsystems of the FIRELAMP simulation model.

CAPABILITIES AND SYSTEM PERFORMANCE

FIRELAMP was intentionally designed to provide low resolution, nonsite-specific information, based on the assumption that greater detail was not critical for forest planning efforts. Initially, we hoped to provide the capability to track detailed information about post-fire vegetation and soil changes; however, we were constrained by computer processing speed, and more importantly, memory limitations. We can't speculate on how many thousands of lines of FORTRAN code were programmed into FIRELAMP. The former research associate tells us that the model took one-half hour to run in batch mode on the mainframe at CSU and that special routines (overlays) were necessary to fit the program within storage restrictions on the CYBER. The compiled version occupied 650 K of memory on the PRIME minicomputer at the Missoula fire lab and took twice as long to run as the mainframe version. To add a more recent perspective, the research associate predicts that the program would probably take about an hour to run on a desktop microcomputer with an intel 80386 processor hooked to a large memory.

REFLECTIONS

FIRELAMP's greatest strength is its interdisciplinary focus; it incorporates the best information then available with the computer technology accessible at the time of the project. Further, our deployment of the management interface distinguishes the model from traditional simulation studies. Finally, we take great satisfaction in the knowledge that we completed our objectives and that all five graduate students completed their M.Sc. theses (Linn 1980; Paustian 1980; Rayburn 1980; Guertin 1983; Wheeler 1985).

In retrospect, the biggest gaps in our knowledge of fire effects produced the greatest shortcomings of the simulation model. These include uncertainties about the effects of fires of different intensity and duration on individual organisms and at the ecosystem level of organization. Computational resources available at the time posed another major limitation. We certainly would have preferred greater resolution in the model, for example to model and track postfire vegetation on each burned area. Initially we had hoped to simulate postfire vegetation on burned sites as affected by individual fire characteristics. Instead, the memory constraints on the CYBER forced us to lump all fires during a given year into several classes, based on broad ranges in fire behavior.

Impacts of management activities and natural disturbances on subsequent resource production also remain difficult to estimate. Where information was lacking we attempted to incorporate the best available knowledge, and we assessed the importance of information gaps through a combination of validation studies and sensitivity analyses. Ultimately, we confirmed that scientists have much to learn about fire effects; and as a profession, we just haven't been in the forestry and fire business long enough to comprehend all the effects of fires and their management.

CHANGES IN FIRE MANAGEMENT DECISION ENVIRONMENTS

In spite of these shortcomings, our approach wouldn't be drastically different if we were to attack the problem today. That is, we would incorporate the best available knowledge of fire behavior and danger, and fire effects on resource outputs. The management interface would continue to play a critical role in maintaining the integrity of the model's performance. Thus our perspectives wouldn't change drastically, in spite of some rather dramatic changes in the fire management decision environment. These changes include improved computing resources, differing perspectives on fire services, and reductions in fire research budgets.

Improved Computing Resources

Improved technology could enhance the efficiency of FIRELAMP's computing environment. Again, we're told that FIRELAMP could be run on networked work stations (costing about $U.S. 20,000 each), with outputs displayed for review and resubmission at each station.

Conceivably, recent advances such as supercomputers and geographic information system (GIS) technology could also be incorporated to improve the model's capabilities. These innovations could improve model efficiency and resolution and greatly improve ability to model postfire vegetation response; however, such improvements might not necessarily increase the accuracy of the information provided because of uncertainties in our knowledge of fire effects.

Differing Perspectives on Fire Services

Back in 1978, there was a feeling that programs such as FIRELAMP might help fire managers become better fire ecologists. Then as now, we knew that fire managers provide a service to the silviculturist and other resource specialists; however, back then we wanted to believe that fire managers could and should become fire effects specialists. Today we realize that the responsibility for integration of fire with land management is not solely the fire manager's; he or she cannot be expected to manage lands without input and advice from the resource specialist. If anything, we may have erred in expecting the fire manager to provide responses to questions best answered by silviculturists, ecologists, and wildlife biologists, among others.

As the fires of 1988 stimulate renewed contemplation of fire's role in ecosystems, perhaps we will see a resurgence in the need for examining, through simulation, various alternative futures for fire and land management. The Yellowstone fires of 1988 have already vitalized concerns on several research fronts, most notably in the arenas of ecosystem studies, policy analysis, and decision systems. These concerns are not new; however, more recently we have been preoccupied with issues such as the urban interface, air quality, and global climate change.

Reductions in Fire Research Budgets

By the time of project completion, the Missoula RD & A Program was winding down. Important personalities had left, and new missions were charted for those who remained behind. In fact, for awhile we had some doubt as to who should take delivery of our final product. Budget reductions had forced priority shifts in the upper levels of U.S. Forest Service research, away from integrating fire in resource management plans. Parenthetically, the period 1982-84 represented a relative lull as far as fire seasons go.

The demise of concern for fire effects has been accompanied by a general de-emphasis on fire research in the United States. This de-emphasis is best exemplified by the current status of fire research in the U.S. Forest Service's experiment stations—there are now fewer scientists, fire research laboratories, and fire research projects than there were 10 years ago. As a result, research directed toward improving our understanding of fire in resource management is virtually nonexistent. We certainly have gained some knowledge about fire in recent years but not much that helps us better understand the role of fire in land management planning.

Figure 3 shows one view of how uncertainty about fire effects increases with time since burn—this uncertainty increases with time until we can invoke our knowledge about plant successional theory. Depending upon the plant community, the time period until uncertainty narrows may be a few years (e.g., in grasslands) to several decades (forests). If you accept the trend line in Figure 3, you probably can agree that basic research is more important than fancier gadgetry in terms of helping us understand the role of fire over an extended time period.

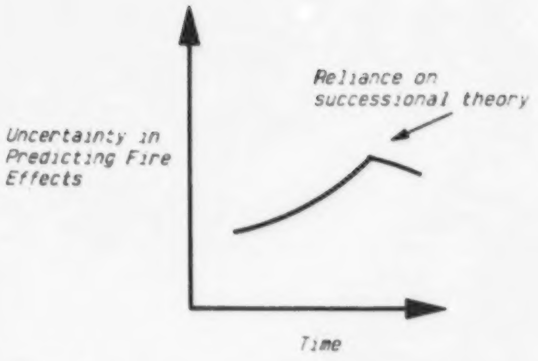

Figure 3. Uncertainty in prediction of fire effects increases with time, but decreases once successional theory can be relied upon.

CONCLUSIONS

For many years we've been part of the computer revolution. We have all marveled at the potential for computers to synthesize encodable information from a large variety of sources and to provide precise insights in a relatively short time period. The key here is the term encodable—the insights we gain from the computer are only as good as the ingoing information, including the model(s) we've encoded for crunching the input data.

FIRELAMP provides a prototype computerized framework for the land management planner to evaluate any number of alternatives against assumptions about resource production and manipulation over time. The effects of different assumptions about climate can also be evaluated. Given what we knew and the available resources at our disposal, we feel that FIRELAMP represents a unique landmark in the annals of fire research.

In the time since project completion, a number of issues have superceded concerns for understanding fire effects, most notably air quality and the urban interface. With effort, these different concerns could be addressed within the FIRELAMP framework, but the decision-maker would still need to weigh outcomes against the political, socioeconomic, and legal concerns that often override resource management decisions today.

Although the decision-making environment has changed profoundly, our biggest stumbling block to more fully integrating fire into land management plans (both then and now) remains the incomplete status of knowledge about fire effects. There is also no consensus among resource professionals on the importance of integrating fire into land management plans.

Perhaps the fire seasons we have experienced in the U.S. during 1985, 1987, and, most importantly, 1988, may once again raise public sensitivity to the need for ensuring the long-term health of natural areas. Simulation provides one of the few viable alternatives for experimenting with future outcomes without undergoing their painful consequences. In many respects, FIRELAMP may simply have arrived ahead of its time. Even so, some parts of the model would be considered crude by current standards; however, we feel that we developed a powerful thinking tool for synthesizing fire effects information across multiple disciplines. The time may now be right for resurrecting the prototype.

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FREEMAN SMITH is a Professor in the Department of Earth Resources at Colorado State University (CSU) in Fort Collins, Colorado. He received a B.Sc. in botany/geology (1961), an M.Sc. in watershed/range management (1969) from the University of Arizona, and a Ph.D. in watershed science/systems ecology (1971) from CSU. Freeman is currently the Director of the International School of Forestry and Natural Resources at CSU.

FIRE WEATHER FORECASTING FOR NEAR-REAL TIME FIRE CONTROL AND USE DECISION MAKING

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ABSTRACT

Fire managers have at their disposal an array of tools to aid in decision making for both prescribed fires and wildfires. Historically, fuels, topography, and weather are the three variables that affect fire behavior. Of the three, weather is the most variable, particularly when current and forecast weather data may not be immediately available. The acquisition of weather data in near-real time is necessary in order for the fire manager to make timely decisions. This paper outlines the types of weather forecasts that are useful to the fire manager's decision making process. The 1988 fire season in the northern Rockies is used to illustrate examples of the near-real time use of weather data by fire management decision makers on many levels.

INTRODUCTION

The U.S. National Weather Service (NWS) is charged with the responsibility of providing weather support to federal, state, and private land managers in support of both suppression and presuppression of wildfires. In addition, support to prescribed fire activities and a host of other land management activities falls within the responsibility of the NWS. Actual weather support to land managers is assigned to meteorologists attached to the fire weather program. The fire weather program evolved in the western portion of the United States during the early portion of this century. Nationwide there are 55 fire weather positions, 28 of which are assigned to the eight western states. Meteorologists in the fire weather program consult with land managers to identify needs and develop a schedule of services. Both routine and nonroutine forecasts are provided to the land managers. Some offices provide scheduled service the year round and others provide it only on a seasonal basis. All offices provide nonroutine services on call year-round.

OFFICE SERVICES

During the wildfire season in the Northern Region (R-1) of the U.S. Forest Service, which is generally confined to July through September, presuppression weather forecasts are made twice daily by NWS fire weather offices. Included in the afternoon forecast package are specific 24-hour numerical forecasts for selected fire danger observation stations. These forecasts are processed through the U.S. National Fire Danger Rating System (NFDRS) and provide land managers with indictions of fuel moisture and burning conditions for their area of concern for the next day. Forecasters are available for consultation and forecast interpretation if land managers have specific concerns.

In addition to twice daily general forecasts, special spot weather forecasts are available on call. These forecasts are designed to be site specific and are used by the land managers to help make decisions on specific fire situations. This could be a wildfire, a naturally ignited prescribed fire, or a preplanned prescribed fire conducted for hazard reduction, site preparation, wildlife habitat improvement, or to accomplish numerous other land management objectives (Goens and Williams 1987).

FIELD SERVICES

Forecasters may be called to the site of a wildfire or a prescribed fire to provide weather support for that specific incident or project. The meteorologist takes with him or her an equipment kit called an Air Transportable Modular Unit (ATMU) (Fig. 1). This kit consists

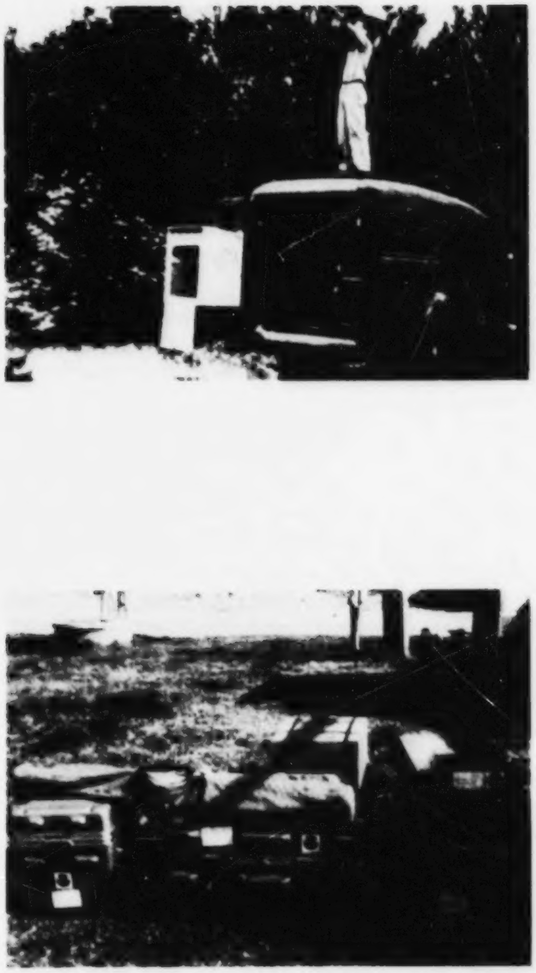

Figure 1. The past and present fire weather field units of the U.S. National Weather Service. Top: early-day mobile unit vehicle. Bottom: modern-day air transportable modular unit.

of a complete satellite receiver and recorder for downlinking and printing charts of observed and forecasted weather. The information received is then transmitted on the national facsimile (NAFAX) service. The kit also includes a computer terminal and modem that enables the forecaster to dial into a host computer at selected NWS offices, a portable weather station for recording on-site weather conditions, a theodolite for taking pilot balloon (PIBAL) readings of low-level wind fields, and necessary office supplies. This kit is packaged in seven pieces and weighs approximately 160 kg. The kit was designed to fit into a light twin-engine aircraft for rapid transport to an incident or project site. Twenty of these kits have been placed in national fire caches around the United States and have been assigned stock numbers in accordance with the national fire cache system.

The ATMU kits were first placed in the national fire cache system in 1987, which turned out to be a record fire year. The kits were dispatched 87 times that year. They had 587 days in the field and were utilized by 41 different forecasters. The records of 1987 were eclipsed in 1988 with 122 dispatches for 880 days in the field by 42 different forecasters.

In the last two fire seasons, forecasters were utilized in the field to a far greater extent that ever before. The mobility of both forecaster and equipment provided the opportunity for this level of utilization. The willingness and dedication of the forecasters, along with the quality of their products, has encouraged the use of the meteorological input in near-real time decision making processes.

CASE STUDY OF THE CANYON CREEK FIRE

The Canyon Creek Fire in Montana was started by lightning on June 25, 1988. The ignition point was within the fire management boundary on the Lolo National Forest's portion of the Scapegoat Wilderness. This area is managed under a wilderness natural fire management plan in which lightning-ignited fires are allowed to freely burn under a specific prescription. A management team met on July 11 to determine whether to suppress the fire or allow it to burn under prescription. Many specific factors were considered, and a fire weather forecaster was consulted on both short- and long-term weather expectations. After all data had been considered, the Canyon Creek Fire was placed in prescription status and was allowed to play its natural role within the Scapegoat Wilderness ecosystem.

The Canyon Creek Fire was monitored daily both on the ground and from the air. The fire remained essentially dormant through the first 3 weeks of July. Fire managers from both the Lolo and Helena national forests monitored weather forecasts primarily through the twice-daily general weather forecasts.

On July 21 the general weather forecast indicated an upper level weather change in store. This altered the plans of fire managers who then requested a special spot weather forecast for the fire. The spot forecast indicated low humidities and stronger winds in store as a dry frontal system passed through the area on July 22. On that day, the fire grew from 526 ha to 4050 ha. Although the fire remained within the prescription boundary, this forecast allowed managers to alert district personnel of the potential for rapid growth and direction of spread. This information aided decisions on visitor use patterns and safety of monitoring and trail maintenance personnel. The weather then moderated for several days and fire growth was again minimal.

The morning forecast on August 9 indicated that another dry frontal system was due with brisk, gusty westerly winds in the fire area. The fire grew to 13 355 ha that day and moved onto the Lewis and Clark National Forest portion of the fire management area. The afternoon forecast on August 9 indicated a continuation of the brisk wind pattern. A three-person management team was assigned to monitor the fire and develop a strategy to keep the fire within the wilderness boundary. Both general and spot forecasts aided this team in accomplishing their tactical objectives for the next 2 weeks.

On August 30 the fire escaped the wilderness boundary on the east side, growing to about 20 235 ha. It was declared a wildfire, and a full Class II incident management team was assigned on August 31. The fire became troublesome again on September 1. A Class I team assumed overall management of the fire, and the Class II team remained as part of the incident organization. The Class I team immediately initiated an order for a meteorologist upon assignment. Due to the tremendous commitment of resources on other wildfires, no forecaster was immediately available. A forecaster was found in Fairbanks, Alaska, was subsequently dispatched, and arrived on the evening of September 6. That was a fateful night—a red flag warning was issued, and a dry cold front with strong gusty winds drove the Canyon Creek Fire across the mountains and onto the plains of Montana, growing to over 97 000 ha.

The fire weather forecaster remained with the Class I team for 13 days on the Canyon Creek Fire. During that time, daily forecasts and briefing services were provided. The forecaster and the overhead team's fire behavior analyst (FBA) spent many long hours working shoulder to shoulder, gaming with possible weather situations to provide input necessary in developing containment and contingency strategies. During that time, evacuation of local residents was necessary at Coopers Lake on the southwest portion of the fire. The evacuation decision was based upon observed fire behavior and a forecast of strong northwesterly winds. Fortunately the winds did not develop as strong as forecast and all structures were spared.

CONCLUDING REMARKS

Fire managers are faced with many difficult decisions through the course of a fire season. Elementary fire courses teach that the behavior of any fire is determined by fuels, topography, and weather. Topography is fixed, fuel inventories and fuel modeling provide necessary fuel input, but weather is dynamic. To make informed decisions, managers must consider all aspects of the fire environment. Fire weather forecasts are available in near-real time to fire managers across the United States. Through fire training courses and active liaison, fire weather forecasters are making their services known. For day-to-day decisions, the general forecasts provide the necessary weather data. For prescribed burning and some wildfire activity, spot weather forecasts can be tailored to the more site-specific problems. For large wildfires or complex prescribed fires, on-site services may be utilized to provide face-to-face consultations and to project specific forecasts.

The 1987 and 1988 fire seasons were of historic significance. New technology allowed the NWS fire weather forecasters to play an active and vital role these past 2 years. The program remains strong, vital, and progressive with new state-of-the-art equipment, a training course for new forecasters, and a commitment to provide service to the land management community. Land managers recognize the capability and commitment of NWS fire weather program personnel and use their forecasts on a near-real time basis for both routine and critical fire management decisions

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SYSTEMATIC ASSESSMENT OF DAILY FIRE PREPAREDNESS REQUIREMENTS

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ABSTRACT

The Forest Fire Preparedness (FFP) System currently used in the Northwest Territories is presented to illustrate a procedure to systematically assess daily fire preparedness requirements. The FFP System consists of four major modules: fire weather elements, the Canadian Forest Fire Weather Index (FWI) System, the Canadian Forest Fire Behavior Prediction (FBP) System, and the Perimeter Control Factor (PCF). The PCF represents the combined effect of fire growth (specifically, the rate of perimeter increase as calculated from the FBP System for given fuel types and slopes) and the frontal fire intensity (represented by the Fire Weather Index component of the FWI System) on the suppression effort needed to control detected forest fires during their initial burning period. The PCF, or line building rate, expressed in m/min, is calculated daily and is used to determine specific initial attack resources for each of the four levels of preparedness. Other factors such as lightning occurrence and distribution, upper ridge breakdowns, and the potential for severe fire weather are also considered. Built into the system are factors such as the size of the fire management unit, fire management organizational structure, values-at-risk, and the historical occurrence and distribution of fires. Future developments and improvements are also discussed with emphasis on integrated computerized fire management systems operating in near-real time environments.

INTRODUCTION

A fire preparedness system is a procedure for fire managers to systematically build up or build down initial-attack resources in response to changes in the fire environment within the context of the agency's fire management mandate. Preparedness is the condition or degree of being able to cope with an anticipated fire situation. Initial attack means the action to halt the spread or potential spread of a fire by the first fire fighting force to arrive at the fire (Merrill and Alexander 1987). In determining the daily initial attack requirements, a number of organizational and environmental factors must be assessed.

The organizational factors are built into the system by default. These factors include size of the fire management unit, fire management organization, values-at-risk, and fire management policy. The Northwest Territories (NWT) has one-eighth of the treed area of Canada. This area is divided into a fire attack zone of 252 000 km², where most of the reported fires are fought, and an observation zone of 975 000 km², where most of the reported fires are not fought (Bailey 1985). In the western arctic, the Government of the Northwest Territories' Department of Renewable Resources has five district offices whose fire management activities are coordinated through the Territorial Forest Fire Centre located in Fort Smith. Protection of life and property is the principal fire management objective followed by protection of wildlife habitat, timber lands, and forest recreational areas.

By the same token, the local fire regime is also built into the preparedness system. The peak fire season lasts about 60 days, from June 15 to August 15. This period is characterized by warm, dry weather with frequent lightning activity and short periods of severe burning conditions. Over the past 20 years, the average annual burn is 163 590 ha and the average number of fires is 283. Most of these fires are caused by lightning, and most of the area burned is in the fire observation zone.

In fire preparedness, the foregoing need only be considered from time to time in response to changes in fire management policy or operational procedures. On the other hand, the environmental factors of preparedness must be assessed daily. These include inputs of fire weather, fire occurrence, fire danger, and fire behavior. The output is a fire preparedness level with explicit initial-attack resource guidelines, alerts, and deployment of resources. The objective of this paper is to examine all of the environmental factors in the systematic assessment of daily fire preparedness requirements using the NWT Forest Fire Preparedness (FFP) System as an example.

NORTHWEST TERRITORIES FOREST FIRE PREPAREDNESS SYSTEM

The NWT FFP System is a procedure, based on potential fire behavior (current and forecast), for the systematic build up or build down of initial-attack resources. The system is characterized by the following features:

- The levels of preparedness are determined by Perimeter Control Factors (PCF), which combine the effect of *fire growth* and *frontal fire intensity*[1] with the suppression effort needed to control fires during the initial burning period following detection. Fire growth is based on the Canadian Forest Fire Behavior Prediction (FBP) System and intensity on the Canadian Forest Fire Weather Index (FWI) System. Both the FWI and FBP systems are major modules of the Canadian Forest Fire Danger Rating System (CFFDRS) (Canadian Forestry Service 1987; Stocks et al. 1989).
- In calculating the fire growth and frontal fire intensity aspects of the system, a constant 10-m open wind speed of 20 km/h value represents a pragmatic upper limit up to which initial-attack efforts are likely to be successful[2].

THE STRUCTURE OF THE NWT FFP SYSTEM

The FFP System consists of four major modules: fire weather elements, the FWI System, the FBP System, and the Perimeter Control Factors (PCF). The 1200 local standard time (LST) fire weather observations from the territorial network of fire weather stations and the forecast weather are the primary inputs to the FFP System. The use of the FWI System and FBP System represent intermediary steps in calculating the PCF. The FFP System assumes that the incipient stage of forest fire growth can be represented by an elliptical shape (Alexander 1985).

Fire Weather Elements

The FFP System uses weather data from two sources to determine the preparedness levels. The current preparedness levels are calculated from the daily 1200 LST weather observations from the territorial network of fire weather stations, except for the 10-m open wind speed, which is held constant at 20 km/h. The 1200 LST observations include dry-bulb temperature, relative humidity, and 24-h rain amounts. The current preparedness levels apply to the day in which they are calculated and serve to verify the previously forecast levels. The forecast preparedness levels are determined from forecast 1200 LST temperature and relative humidity values, one and two days in advance. Again, wind speeds are held constant at 20 km/h and rainfall is not forecast. By not considering rainfall, the forecast fire preparedness is biased to the dry, high side. The system is recalibrated daily when the preparedness level is calculated from the current 1200 LST weather inputs, which include the 24-h rainfall amounts. The forest weather values are applied after the calibrations; thus, the forecasts are always projected from a known base. Rainfall, therefore, is an input only when it becomes a known quantity.

FWI System

The FWI System has been used in the Northwest Territories since 1971 when it was first introduced to fire management agencies in Canada by Forestry Canada (then the Canadian Forestry Service). Since its introduction in the NWT, the FWI System has been used with increasing confidence as a guide to planning and preparing for fire management activities such as detection, presuppression, and suppression. The FWI System consists of six components (Van Wagner 1987).

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[1] Frontal fire intensity, which is synonymous with Byram's (1959) fireline intensity, represents the rate of heat energy release per unit time per unit length of fire front (I). Flame size is its main visual manifestation. Numerically, it is equal to the product of the net heat of combustion (H), quantity of fuel consumed in the flaming front (w), and linear rate of spread (r)($I = Hwr$). See Alexander (1982) for further information.

[2] Crown fire spread is predicted to occur, if the fire is burning on level terrain, at an Initial Spread Index (ISI) of 12 or greater according to the 1984 interim edition of the FBP System (Lawson et al. 1985). An ISI of greater than or equal to 12 can be attained, with a 10-m open wind of 20 km/h, at a Fine Fuel Moisture Code of greater than 89 (Canadian Forestry Service 1984; Van Wagner and Pickett 1985). A 10-m open wind of 20 km/h, coincidentally, represents a typical average value for the daily burning period in the forest areas of NWT during the fire season (Atmospheric Environment Service 1982).

Three of the components are fuel moisture codes whose values give, in turn, relative numerical ratings of the moisture content of fine fuels (needle litter), medium fuels (loosely compacted organic layers of moderate depth), and heavy fuels (deep, compact, organic matter). The three remaining components are fire behavior indexes, two of which are intermediary steps in calculation of the third, the Fire Weather Index (FWI) component itself. The NWT FFP System uses three of the six components of the FWI System: the Fine Fuel Moisture Code (FFMC), the Initial Spread Index (ISI), and the FWI.

The FFMC component of the FWI System represents a numerical rating of the moisture content of litter and other cured fine fuels (Canadian Forestry Service 1984). The FFMC, which integrates the effects of wind, speed, temperature, relative humidity, and rainfall, over the past couple of days, is a good guide to ignition probability and general burning conditions. Fine fuels are abundant, and winds spread throughout the treed area of the NWT. In all forest fuel complexes, mosses, lichens, grasses, and small downed-dead woody material are found in sufficient quantities either singly or in combination to carry fire. Except for wind, the fine fuel component in northern forest fuel types is the single most important factor contributing to the development and spread of forest fires.

The ISI component of the FWI System represents a numerical rating of the expected rate of fire spread. It combines the effects of wind and FFMC on rate of spread without the influence of variable quantities of fuel (Canadian Forestry Service 1984). The ISI is an input to the FBP System and is used to predict the head fire rate of spread (ROS) and specific fuel types. This is the basis for the calculation of the rate of perimeter increase (P_i) of uncontrolled fires over time.

The FWI represents a numerical rating of fire intensity that combines ISI and Buildup Index or BUI (Canadian Forestry Service 1984). The proportion of an elliptical-shaped fire perimeter (Fig. 1) that actually needs control action is scaled according to the frontal intensity of the fire (Fig. 2) as represented by the FWI (Alexander and De Groot 1988). This amount of potential effort, expressed as a fraction, is called the Fire Control Factor (FCF). The FCF, a function of the FWI, is given by the following equations (Fig. 3):

$$\text{FCF} = 0.00023436(\text{FWI})^{2.6302},\ \text{FWI} \leq 24 \qquad [1a]$$

$$\text{FCF} = 1.0,\ \text{FWI} > 24 \qquad [1b]$$

The value of the FCF varies between 0.0 and 1.0 as the value of the FWI varies between 0 and 24. For FWI values greater than 24, the FCF has been set constant to a value of 1.0. Expressed as a percent of the total perimeter, the FCF varies between 0 and 100 as the FWI varies between 0 and 24. Other elliptical fire growth containment models assume that 100% of the perimeter must be controlled. (Mees 1985) or some constant proportion such as 40% (Potter et al. 1981; Martell et al. 1984), regardless of the burning conditions.

This relation is presently based in part on the experiences of fire control personnel in the Northwest Territories supplemented by published and unpublished[1] documented cases of fire behavior in FBP System Fuel Type C-2 (Kiil 1975; Newstead and Alexander 1983; Alexander and Lanoville 1987). There were, however, two key data points: 1) the FCF should equal 0.1 when the FWI = 10, and 2) when the FWI is equal to or greater than 24, currently the extreme fire danger class threshold value in the Northwest Territories, the FCF should equal 1.0.

FBP System

The FBP System produces quantitative outputs of selected fire behavior characteristics for major Canadian fuel types (Lawson et al. 1985). The FBP System is used in the FFP System to determine the potential growth of free-burning elliptical-shaped fires (Fig. 1) in boreal spruce stands on near-level topography. Boreal spruce (FBP System fuel type C-2) was chosen as the most representative fuel type in the NWT for the following reasons:

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[1] Lanoville, R.A.; Schmidt, R.E. 1985. Wildfire documentation in the Northwest Territories: a case study of Fort Simpson-40-1983. Pages 17-22 *in* M.E. Alexander, compiler and editor. Proceedings of the second western region fire weather committee scientific and technical seminar. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Study NOR-5-191 File Report 9.

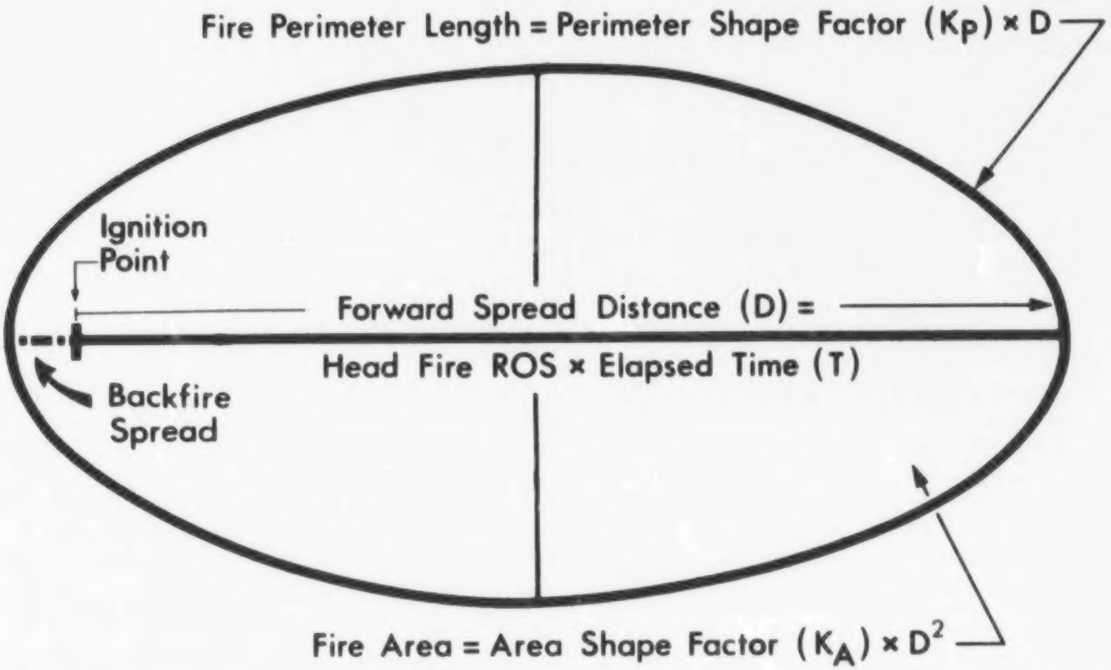
Fire Perimeter Length = Perimeter Shape Factor (K_P) × D
Ignition Point
Forward Spread Distance (D) =
Head Fire ROS × Elapsed Time (T)
Backfire Spread
Fire Area = Area Shape Factor (K_A) × D^2

Figure 1. The free-burning elliptical-shape wind-driven fire on level terrain with a length-to-breadth ratio (L/B) of 2.0:1 (Alexander and Lanoville 1989). The shape factors for calculating fire area and perimeter length would be based on the "focus approach," which indirectly accounts for backfire spread (Alexander 1985).

1. Spruce growing in singular stands or in combination with other tree species covers most of the treed area of the Fire Attack Zone;
2. Nearly all fires resulting from lightning ignitions develop and initially spread in this fuel type; and
3. The vast majority of the fire control experience, upon which the requirements for suppression action are determined, has been in this fuel type.

Using the ISI component of the FWI System (Van Wagner and Pickett 1985), the head fire rate of spread (ROS) on level terrain for boreal spruce, expressed in m/min, is given by the following equation taken from the user guide[4] to the 1984 interim edition of the FBP System:

$$\mathrm{ROS} = 112.8\,(1 - \underline{e}^{-0.0238\mathrm{ISI}})^{1.861} \qquad [2]$$

The rate of perimeter increase (P_i), needed to calculate the Perimeter Control Factors (PCF) in the FFP System, is determined as follows:

$$P_i = K_p\,(\mathrm{ROS}) \qquad [3]$$

where, the ROS is determined from Equation [2] and K_p is the Perimeter Shape Factor, which is equal to 2.75 for a 10-m open wind speed of 20 km/h (Alexander 1985). This corresponds to an ellipical-shaped fire with a length-to-breadth ratio (L/B) of about 1.8:1 (Alexander 1985). The rate of perimeter increase is expressed in m/min.

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[4] Alexander, M.E.; Lawson, B.S.; Stocks, B.J.; Van Wagner, C.E. 1984. User guide to the Canadian Forest Fire Behavior Prediction System: rate of spread relationships. Interim ed. Environ. Can., Can. For. Serv., Fire Danger Group. Ottawa, Ontario. [First printing July 1984; revision and second printing Sept. 1984.]

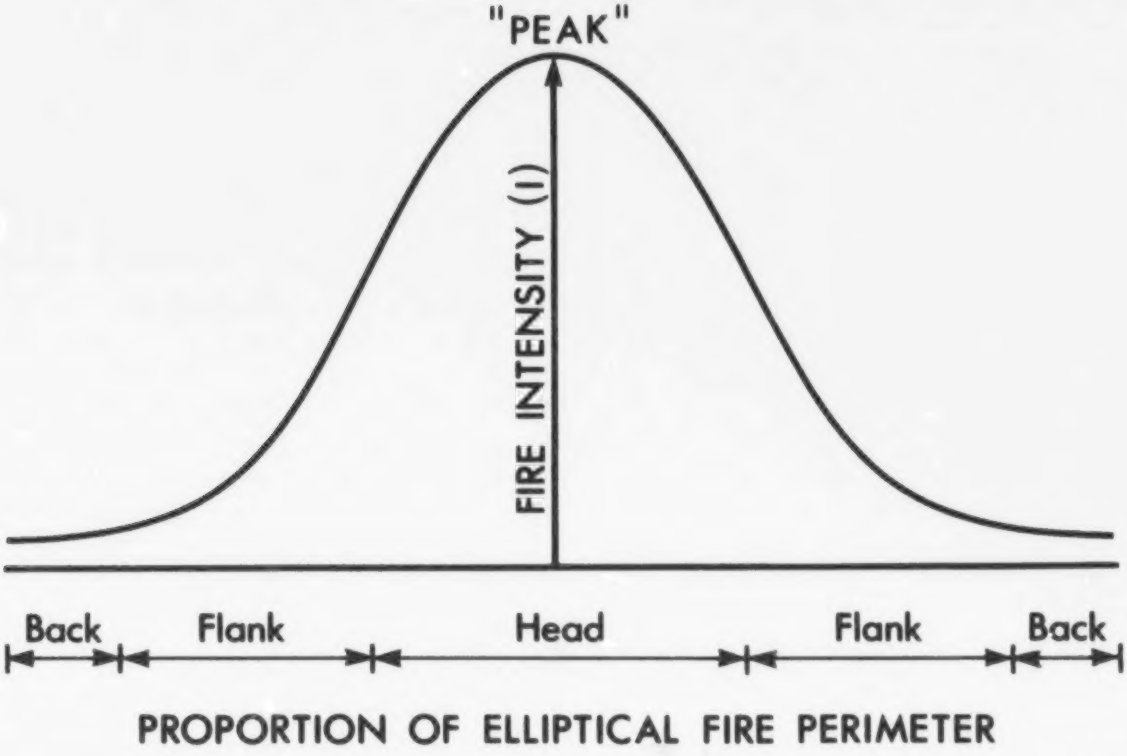

Figure 2. Variation in frontal intensity around an elliptical-shaped fire front (Catchpole et al. 1982). The proportion varies according to the L/B which is in turn a function of wind speed for a given fuel type.

Perimeter Control Factors

The PCF represents the combined effect of fire growth (specifically, the rate of perimeter increase) and the frontal fire intensity (represented by the FWI) on the suppression effort needed to control detected forest fires during their initial burning period. The PCF, expressed in m/min, is calculated as follows:

$$PCF = FCF\,(P_i) \qquad [4]$$

where, the FCF is the Fire Control Factor determined from Equation [1a] or [1b] and P_i is the rate of perimeter increase determined from Equation [3].

FIRE BEHAVIOR AND SUPPRESSION INTERPRETATIONS

In practice, a PCF value is calculated from either the current or forecast weather data from the fire weather stations located within the boundaries of the five administrative districts in the western arctic. Each weather station represents an area with its own array of terrain and forest fuel types. The PCF value may be adjusted for slope in mountainous areas or for fuel types other than boreal spruce. Also, the PCF value may be weighted according to the percentage of the total administrative area the weather station represents. This option allows the daily adjustment

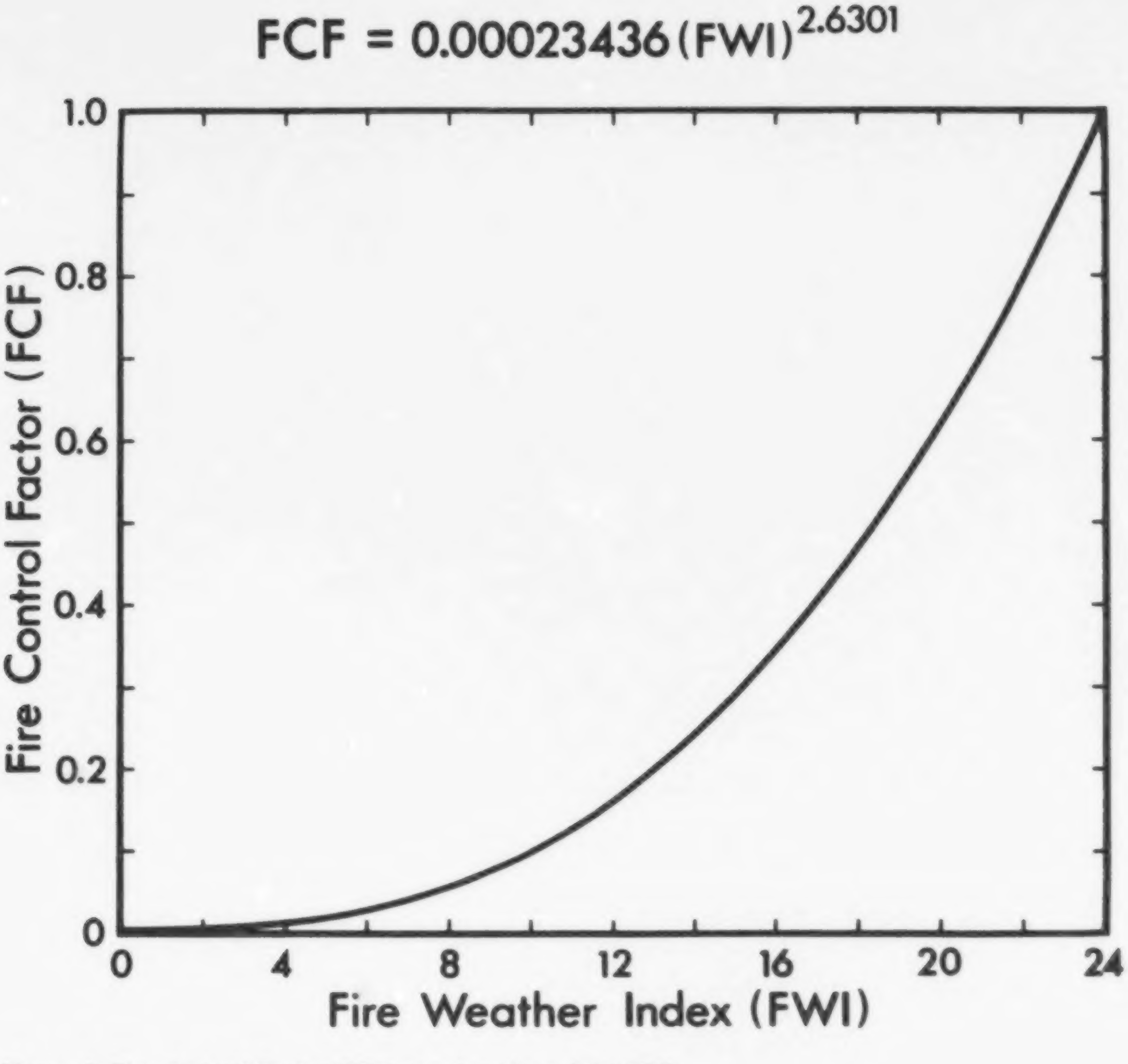

Figure 3. Fire Control Factor (FCF) as a function of the FWI.

of spatial changes in forest fuel condition and potential fire behavior in response to surface weather conditions.

Every day during the fire season, the PCF values from the representative fire weather stations are calculated and a weighted average determined for each of the five administrative districts. The current or forecast preparedness level is determined from a range of PCF values: Level 1 (0-2.9), Level 2 (3.0-14.9), Level 3 (15.0-29.9), and Level 4 (30+). A generalized interpretation of fire behavior and suppression requirements is given below for each level (Fig. 4):

Level 1: Smoldering ground or creeping surface fire. Fire brands and going fires tend to be virtually self-extinguishing unless high Buildup Index (BUI) and/or Drought Code

(DC) values prevail, in which case extensive mop-up is generally required.

Level 2: Low-to-moderately vigorous surface fire. Direct attack at the fire's head or flanks by fire-fighters with hand tools or power pumps are generally successful. Air support may be required. Constructed fire guards should hold.

Level 3: Highly vigorous surface fire or passive crown fire (extensive torching). Control action at fire head may fail. Suppression action with retardant aircraft, water skimmers, or bucket-equipped helicopters are generally successful along the fire's flanks.

Level 4: Active crown fire or "conflagration" type fire run. Suppression actions may have to be delayed until conditions ameliorate.

ALLOCATION OF RESOURCES

The initial-attack resources in type and number for each of the preparedness levels are assigned on a district basis in the form of resource guidelines. In developing the guidelines, a traditional approach has been used to handle the problem of fire risk (i.e., the potential number of ignition sources). Within the scope of the collected experience and judgment of NWT fire managers, the resource guidelines for each level of preparedness reasonably reflect the number and type of fires that could be attacked and controlled in one day.

The initial-attack infrastructure within the fire attack zone is designed to rapidly build up and build down resources. For example, the Department of Renewable Resources maintains 11 main initial-attack bases located at administrative headquarters during the fire season. Initial attacks are launched from these bases at levels 1 and 2. Whenever levels 3 or 4 are attained, any number or all of the secondary initial-attack camps may be opened. These camps are strategically located throughout the Fire Attack Zone principally to reduce the area covered by loaded patrols, and they subsequently reduce the distance travelled to new fire starts. Most initial-attack camps are designed to accommodate up to 25 fire fighters and two to three medium lift helicopters. In addition to the initial-attack bases and camps, the department operates two air tanker groups—a DC-6 land-based

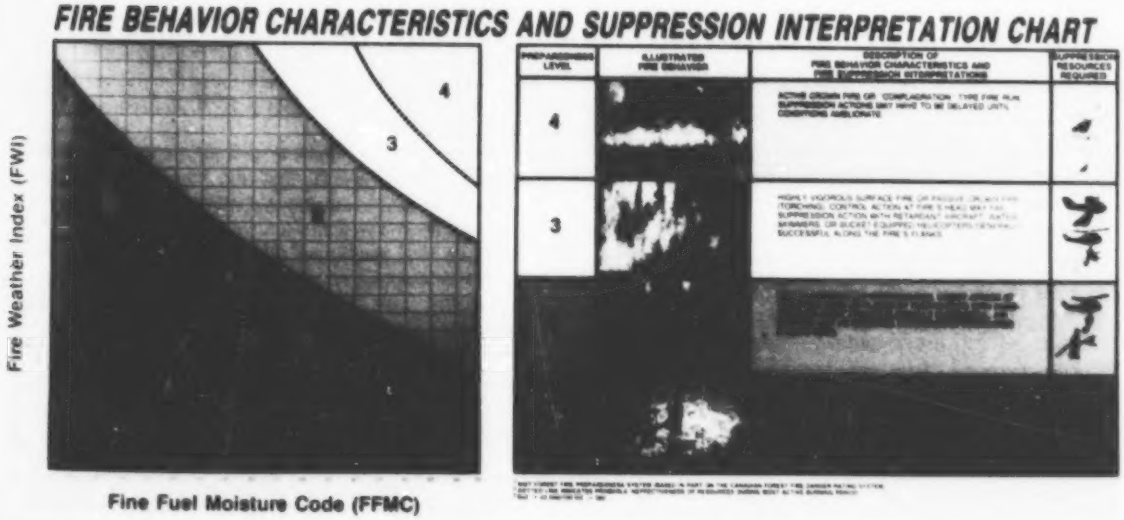

Figure 4. Wall poster associated with the Northwest Territories' Forest Fire Preparedness System. The actual poster measures 40 × 80 cm.

tanker and two CL-215 water skimmers. These groups operate out of any one of the six air tanker bases.

The NWT FFP System combines the effect of fire spread and fire frontal intensity with the effort needed to control the spread of forest fires. That effort is expressed in the PCF value calculated from weather data from representative fire weather stations or forest weather data using the FWI and FBP systems of the CFFDRS as intermediary steps. The PCF values may be adjusted for terrain, forest fuels, and size of the representative area before they are averaged and the fire preparedness level determined. This process must be done daily in order to properly assess changes in the fire environment. Districts also consider other atmospheric features such as lightning occurrence, upper ridge breakdowns (Janz and Nimchuck 1985) and critical synoptic-scale fire weather types (Street and Birch 1986). Along with these and organizational considerations, the initial-attack resources guidelines of the system are used to determine an appropriate allocation and deployment of initial-attack resources.

IMPROVEMENTS AND DEVELOPMENTS

The NWT FFP System has been in operation for two fire seasons. In using the system, the field staff have increased their awareness of their own fire environments, particularly in estimating potential fire starts and subsequent fire behavior. This interest has directed attention to evaluating and expanding the network of fire weather stations, expanding the lightning locator system, and establishing more strategically located initial-attack camps for earlier detection and faster initial-attack response.

Use of the FFP System has brought into clearer focus the research and development needed to make it more effective. Fire occurrence prediction is not a formal part of the system. Ideas about predicting man-caused fires will soon be incorporated into the system, but the real improvement would be in the prediction of lightning-ignited fires.

We need more quantified information about fireline production rates for both ground and air attacks. The FFP System is based on the PCF, which represents the line-building effort needed to control detected forest fires during their initial burning period. This would be valuable in assigning the appropriate complement of personnel and equipment to each fire situation. Related to this would be the development of a computer-driven dispatch system. Such a system would be particularly useful during periods of multiple fire starts under varying environmental conditions.

Finally, the system is but one link in the chain from fire prevention to fire suppression. Our aim is to complete the integration of the various links into a computer-driven fire management system operating in near-real time.

ACKNOWLEDGMENTS

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SPATIAL DISPLAY OF PREDICTED FIRE BEHAVIOR

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ABSTRACT

Deployment, manning, and dispatching are geographically driven activities that respond to geographically based phenomena: changes in fire weather, fire danger, and potential fire behavior. Information systems or decision-aids designed to support the above activities should therefore not only be structured geographically but should display the information spatially and graphically. This paper describes a flexible personal computer-based system for the spatial display of fire behavior information including spread rates, area growth, crowning potential, and time to reach a given size. Such rapidly available, spatially displayed information provides the fire dispatcher or fire manager with a powerful decision-support tool in the form of an immediately comprehensible visual display of potential or actual fire behavior on the landscape.

INTRODUCTION

Fire management is a spatial problem. The essential questions relate to when, where, and how many resources should be distributed across the landscape. These questions can only be answered on the basis of prediction; prediction of fire weather, fire danger, fire occurrence, and fire behavior. Secondly, fire management represents an immediate problem where responses are required on a day-to-day and hour-by-hour basis, with changes in fire weather, fuels, topography, and fire behavior as fire moves across the landscape. This unique requirement for rapid response in a spatial context leads to the need for a dedicated high-speed processing capability and high quality graphics for the display of information. This paper describes a system that will rapidly translate weather, fuel, and topographic data into spatial fire behavior information.

THE PROBLEM

Fire behavior varies over space and time as it is driven by weather, fuels, and topography. The difficulty lies with the dynamic nature of these input variables. Weather changes almost continuously, and even where weather is measured only once a day, diurnal variations in weather parameters must be addressed. With the move to hourly weather information the data handling task becomes even larger. Fuel type can also change dramatically over the short term with natural or man-made disturbances, but even more importantly fuel state changes continuously with weather. While topography changes little over time, it can change dramatically over space and exerts a strong influence on fire behavior.

The problem, then, is to be able to transform vast amounts of dynamic spatial and temporal data on weather, fuels, and topography into usable information that can be assimilated easily and rapidly by the fire manager.

AN APPROACH

The basis of all fire management information systems is the transformation of weather data into relative ratings of the moisture content of standardized fuels and potential fire behavior. The Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987) of the Canadian Forest Fire Danger Rating System (Stocks et al. 1989) provides three fuel moisture codes and three fire behavior indexes (Canadian Forestry Service 1984). At the first level of information these can be used individually or combined in various ways and displayed geographically to provide an indication of where and when resources should be deployed or to what level manning-up should occur.

The limitations of such a system are that fuels and topography are not included, that the display is only one of relative ratings, and that the scale of the display is set by the distribution of weather stations rather than by the scale of the actual fuels and topography of the landscape from which the weather data has been obtained. These limitations can be addressed to some degree by dividing the landscape into smaller units based on initial attack zones or land survey units such as townships, ranges, or sections, and assigning an average or selected fuel type and slope to each of these units. The Canadian Forest Fire Behavior Prediction (FBP) System (Lawson et al. 1985) can then be used to combine the fire behavior indexes of the FWI System with the average or selected fuel type and slope to generate quantitative estimates of potential fire behavior to each unit.

While the above procedure introduces quantitative fire behavior into the system, it also introduces the problems of averaging. Fire does not respond to the average situation but to the specific fuel type and slope at the point of ignition. In fact, the average is often an artifact that does not exist at all. This issue is particularly important during initial attack where the behavior of the fire, up to approximately 1 ha in size, is of crucial importance. The need, therefore, is for an alternative to this relatively coarse resolution of fuel types, topography, and fire behavior, to a resolution at which fuel type and topographic data is actually available. Remote sensing and geographic information system (GIS) sources can provide data at a resolution of a few square metres, and given appropriate classification and enhancement procedures for the former, broad fuel can be typed to a similar level of resolution.

It is true that fuel types themselves are broad approximations and that there is a limit to the density of a weather station network that provides the basic data. This does not obviate the need, though, for fire behavior information to be at the best resolution possible.

A potential problem is that the greater the resolution, the greater the data and calculation load and the slower the response time for information delivery. For example, imagine a landscape of 50 000 ha with a resolution of 1 ha. To calculate spread rates and display them would require scanning 50 000 1.0-ha cells to determine the fuel type and the FWI System components; the Initial Spread Index (ISI) and the Buildup Index (BUI), doing 50 000 calculations of rate of spread, assigning the results to one of a number of classes, and then assigning the classes by color code. This problem can be solved simply by doing the spread rate calculations ahead of time and creating a matrix of solutions for all possible values of the ISI, fuel types, and slopes. Thus, the computer merely has to look up the matrix to determine the spread rate. With contemporary personal computers, depending on the model and the configuration, the display of results can be completed in 1-5 seconds. By anyone's judgment, this is a near real-time response.

Fire Spread Rates

Figure 1 portrays a simplified, shaded (rather than color) example of such an output. The landscape portrayed contains 50 000 cells, four fuel types, and the input from one weather station. Once such a system has been created then the addition of further input variables or output parameters can be added with ease. The next step, for example, might be the addition of a more dense weather network, since this is the "softest" of the input variables with respect to resolution. Figure 2 portrays the same landscape as in Figure 1 but the landscape is assigned to six rather than one weather station.

A major variable that is still missing is topography. With the increasing availability of topographic and elevational data from sources such as GISs this can now be included. Using elevational data, slopes can be assigned to each cell, and the computer simply scans this data as it does fuel types and fire danger indexes. In this case a three-dimensional matrix of spread rates is created in which each layer of the matrix represents a different ground slope. Thus, the determination of rate of spread for each cell remains a look-up exercise that can be completed very rapidly. Figure 3 displays the same landscape as in the two previous figures but with elevational or slope data added.

Fire Growth Times

Spread rate is only one fire behavior parameter, and each fire manager may have a preference for other output parameters for activating preparedness systems. An obvious choice might be fire growth, or the time for fire to reach a given size. If each cell is one hectare in size, then a manager might wish to know, particularly in an initial attack context, how long it will take to burn each cell.

This is a more complex situation because fire growth is two dimensional and no longer depends on the ISI alone but on the relative contributions of the wind and the Fine Fuel Moisture Code (FFMC) to the ISI. Once again a matrix is created, but this time of

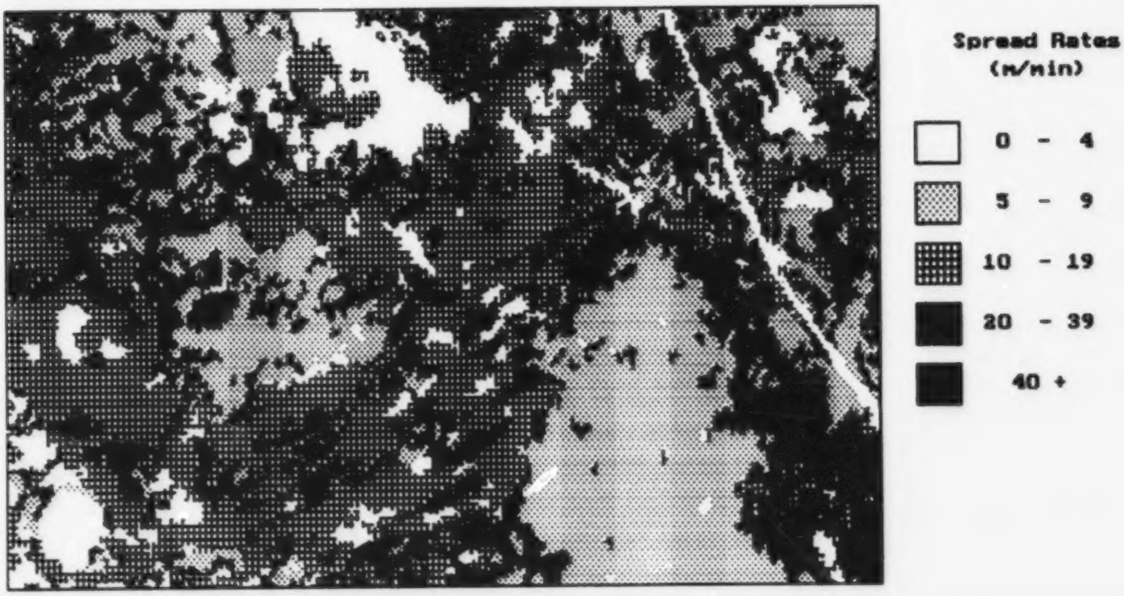

Figure 1. Display of head fire spread rates on a 50 000-unit landscape with one weather station, four fuel types, and zero percent slope.

the length-to-breadth (L/B) ratios (Alexander 1985) versus spread rates, with the output as the length of time to reach 1 ha. Times are then assigned to number of classes, which in this case are <15, <30, <60, and >61 minutes (Fig. 4). The simple L/B approach is acceptable in this context because each cell is considered homogeneous with respect to fuel type, and fire growth beyond each cell is not of concern.

Crowning Potential

Another output parameter of interest might be crowning potential, which is largely a function of rate of spread and fuel continuity as expressed in height to live crown. Figure 5 displays the change in crowning potential over a period of 6 hours at 2-hour intervals. The change in crowning potential in this series is driven by a diurnal variation in weather parameters that is part of the program (Feunekes and Methven 1988). Such a diurnal pattern would have to be tailored for each geographic region. If hourly weather values are available, then these should be used.

CONCLUSIONS

The success of proactive fire management is highly dependent on quality information that is both timely and easy to assimilate. Because fire management is a spatial activity, the information should also be presented in a spatial format. With spatial information from remote sensing and GIS sources becoming readily available, the fire manager now has the capability to integrate this information with fire weather and fire danger information to generate a wide choice of geographically specific information on potential fire behavior.

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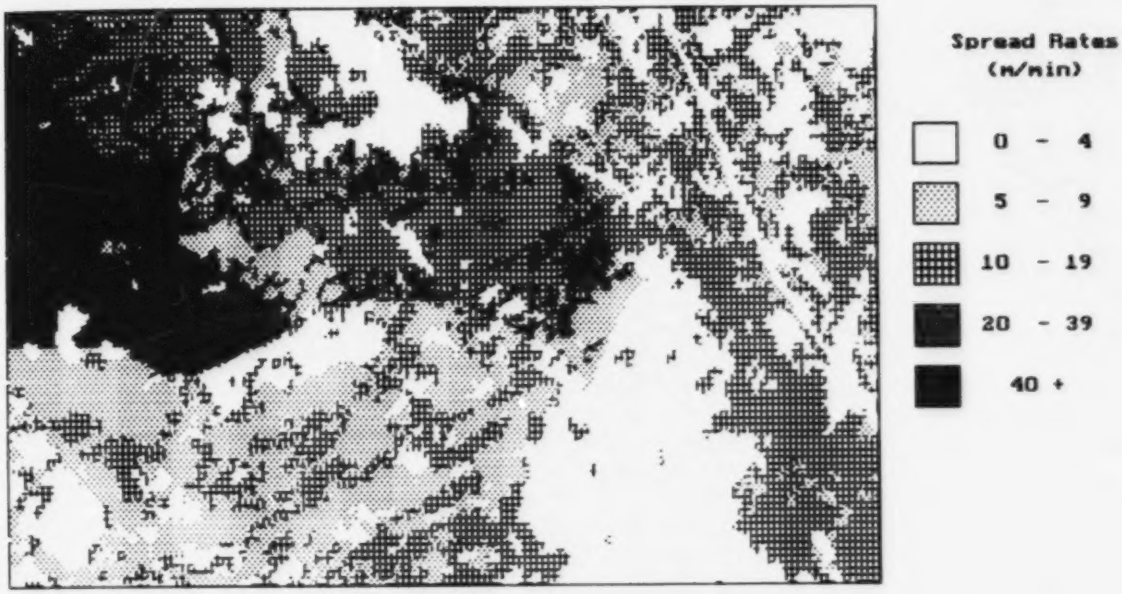

Figure 2. Display of head fire spread rates on a 50 000-unit landscape with six weather stations, four fuel types, and zero percent slope.

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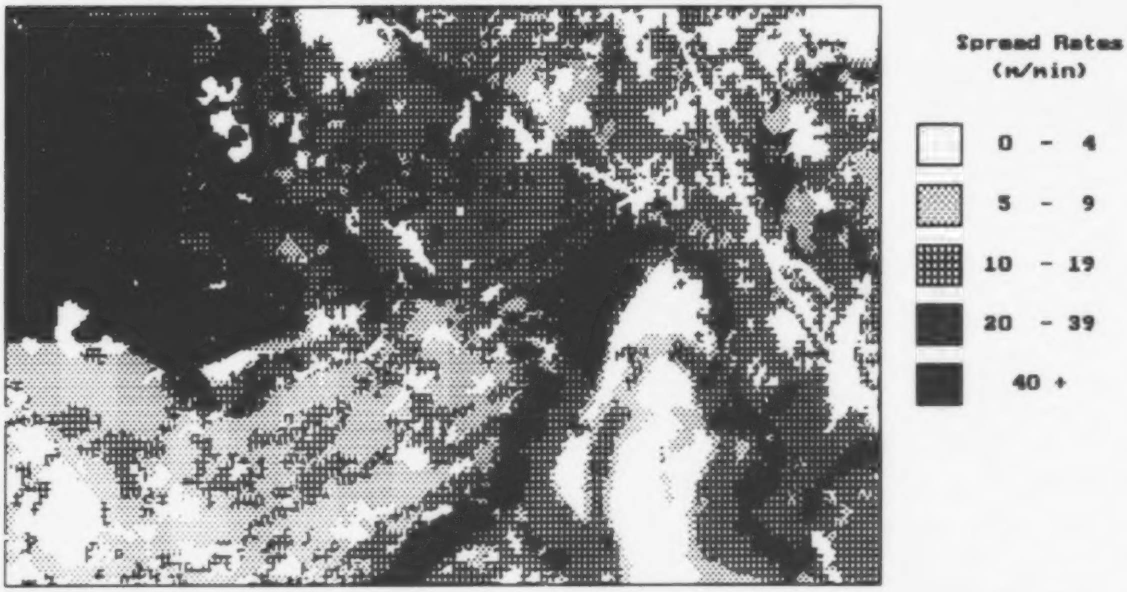

Figure 3. Display of head fire spread rates on a 50 000-unit landscape with six weather stations, four fuel types, and multiple slopes.

IAN METHVEN is the President of R/EMS Research Ltd. and a Professor of Forestry and Fire Management in the Department of Forest Resources at UNB. He received a B.Sc. degree in forestry from UNB (1969) and a Ph.D. degree in tree physiology from Duke University (1972). He is also a graduate of the Forestry Technology School at Hinton, Alberta (1964). Ian worked as pulpwood cutter in west-central Alberta (1962-63) prior to joining the Alberta Forest Service as a ranger (1963-65). He was a Fire Research Officer with the Canadian Forestry Service at the Petawawa National Forestry Institute from 1969 to 1979. Ian has been employed at UNB since 1979. He is the founder of R/EMS, a consulting and software development company in the natural resources field, specializing in wildland fire management since 1986.

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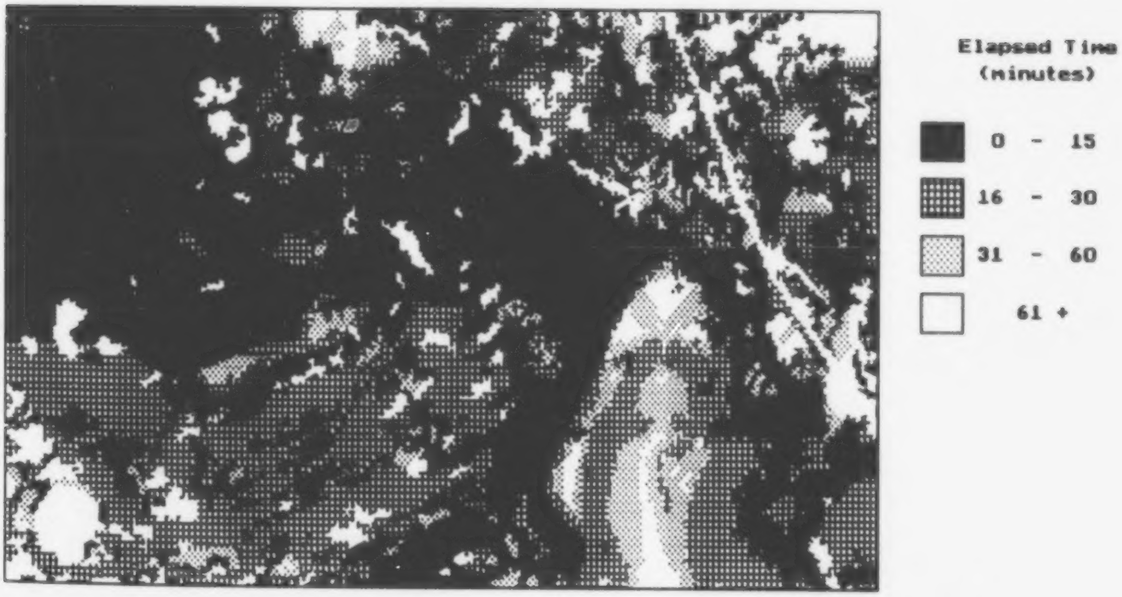
Elapsed Time
(minutes)
0 - 15
16 - 30
31 - 60
61 +

Figure 4. Display of time classes for fire to attain 1 ha in size (i.e., a single unit) on a 50 000-unit landscape with six weather stations, four fuel types, and multiple slopes.

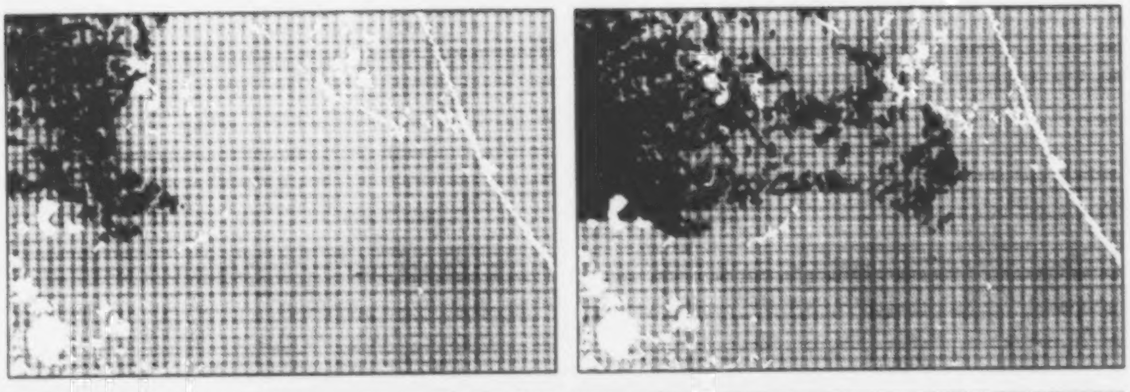

Figure 5. Display of crowning potential over a 6-hour period at 2-hour intervals on a 50 000-unit landscape with six weather stations, four fuel types, and zero percent slope. The dark, black areas represent crowning according to the basic criteria established by Lawson et al. (1985).

TECHNICAL SESSION IV:

FIRE MANAGEMENT ACTIONS AND PRACTICES

FIRE MANAGEMENT ACTIONS AND PRACTICES

OPENING REMARKS

Moderator:

Robert P. Bailey
Department of Renewable Resources
Government of the Northwest Territories
Fort Smith, Northwest Territories

Welcome to Technical Session 4: Fire Management Actions and Practices. What is fire management? We all use this term every day, but it may mean something different to each one of us. Let's take a quick look at a definition widely accepted in Canada:

> Fire Management—The activities concerned with the protection of people, property, and forest areas from wildfire and the use of prescribed burning for the attainment of forest management and other land use objectives, all conducted in a manner that considers environmental, social, and economic criteria.
>
> Fire Management represents both a land management philosophy and a land management activity. It involves the strategic integration of such factors as a knowledge of fire regimes, probable fire effects, values-at-risk, level of forest protection required, cost of fire-related activities, and prescribed fire technology into multiple-use planning, decision making, and day-to-day activities to accomplish stated resource management objective. Successful fire management depends on effective fire suppression capability, and consideration of fire ecology relationships[1].

During the previous three sessions we have heard about fire management problems and opportunities, fire research programs in support of fire management decisions and solutions, and the role of new technologies in fire management activities. Now, just how do we, as fire managers, put into practice the research and new technologies? How do we respond to the opportunities?

Foremost on our list of priorities as fire managers is the protection of people and property from wildfire. This priority affects all of our decisions as fire managers and has influenced our actions and practices on mutual aid, preplanning, prevention of man-caused fires, enforcement of legislation, and use of prescribed fire.

Today's fire manager represents the bottom line of all the opportunities, research, and technology available. He is the artist who carefully executes the fire management plans to accomplish stated resource management objectives. In this session we will hear from eight fire managers who will inform us on several key components of fire management actions and practices. One component is cooperation on a local and international basis. Another component is the integration of fire into forest and land use management activities, and a third is fire prevention.

THE AUTHOR

BOB BAILEY is currently the Director of Fire Operations for the Government of the Northwest Territories' Department of Renewable Resources located at the Territorial Forest Fire Centre in Fort Smith. He obtained a diploma in Forest Technology (1971) and a B.Sc. degree (1973) from Lakehead University. His fire career began in 1970 as a seasonal suppression crew member. In 1973, he joined Abitibi Paper's Woodlands Division for a one-year period. Bob has worked as an Assistant Resource Management Officer and District Protection Officer in Inuvik, NWT for Indian and Northern Affairs Canada from 1974 to 1976. He moved to the fire center in Fort Smith in 1976 as the Training and Standards Officer prior to becoming Head of Fire Control in 1981. With the transfer of the fire program from the federal government to the GNWT in 1987, he assumed his present position.

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[1] Merrill, D.F.; Alexander, M.E.; editors. 1987. Glossary of forest fire management terms. 4th ed. Natl. Res. Counc. Can., Can. Comm. For. Fire Manage., Ottawa, Ontario. Publ. NRCC 26516.

PROTECTING PEOPLE AND HOMES FROM WILDFIRE IN COLORADO'S MOUNTAIN FORESTS

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ABSTRACT

In 1965, the Colorado State Forester's office began to recognize the threat of wildfire to people and improvements in forest land developments. Although no severe losses had yet occurred, methods to prevent such losses and to better handle wildfires in developed areas were begun. A wider, holistic approach to wildfire protection was initiated through land-use planning and a wildfire hazard mapping system. State fire equipment, land management, forest publications, fire training, and fire organization have also been changed to recognize nonforest values. Activities continue to be developed and modified to meet changing needs and technology. This paper chronicles the various approaches used for protecting people and developments in Colorado's wildfire protection program.

INTRODUCTION

Colorado's wildfire protection challenges are typical of the western United States—dense stands of coniferous forests, brush-covered slopes at lower or drier elevations, and large areas of grassland. The protection methods used for nonfederal wildlands are also similar to other states: rural fire departments, counties, and the state forester all have responsibilities. Colorado, however, has taken a slight twist not seen in other areas. By state law, the county sheriff handles many of the emergencies and is responsible for controlling forest and prairie fires. The state forester assists the sheriff and rural fire departments until such time as the fire is beyond local capability.

The scenic attractions, favorable climate, and superb outdoor recreation opportunities have attracted many new residents to the state over the past 25 years. Many of these new residents desire to live in rural areas, and they have built their year-round residences in the forest. Thus, the urban-rural interface and all its attendant problems came upon Colorado years ago.

The extra problems of protecting this interface during forest fires was realized by the Colorado State Forest Service (CSFS) in 1965 as a result of several new mountain subdivisions. They contained sharp, narrow access roads, dense coniferous forests, little or no water supplies for fire protection purposes, and clearing slash was left virtually everywhere. No thought or provisions had been made for protecting the developments against fire of any kind. Other similar developments soon followed. The land rush for mountain homesite property was on! The improvements of ski areas and the desire for a nice home made values-at-risk skyrocket. As a consequence, damages were increasing, and some structural losses were beginning to occur.

Mountain pine beetle also became more active. Dead bug trees, often in huge numbers, soon added to the protection headaches. It had become apparent to the CSFS that fire protection in Colorado needed something extra, something other than just more of the traditional protection methods of pumper trucks or airplanes.

A first step was to change state fire engine designs to better meet the total fire problem facing rural fire departments. Larger pumps were made standard, as were larger tanks, standard hose threads, and colors. Agreements were written for the equipment to be used for any emergency that threatened life or property, not just wildfire. State forestry fire engines were made and repaired by the CSFS and loaned to local rural fire departments at no cost. Fire departments operated the engines at no charge to the state.

The rural fire departments also needed and received greater training in wildland fire behavior and tactics. Until the appearance of a state forestry employee on training night, many fire departments had received no wildland fire training. Thus, began in the mid-1960s what is now called cross-training of rural fire departments.

In 1968, a procedure was worked out with Jefferson County for review of proposed subdivision plans. The county voluntarily sent copies of the plans to the CSFS district forester for review and comment about wildfire protection needs or hazards. As a result, many hazardous proposals were stopped or modified before they began, and the county soon started to adopt better development standards to accommodate the fire protection needs.

In 1969 the state forest service supported a Colorado State University graduate student, James Hulbert, to conduct an interview-survey of mountain subdivision homeowners and subdividers about the risk of wildfire (Hulbert 1970). The results surprised few foresters; most of those interviewed perceived little or no wildfire threat, usually because no fire had recently occurred (Hulbert 1972).

Despite many good efforts, developments continued to be proposed for areas regardless of their inherent fuels or topographic problems. It seemed to some in the state forest service that those problems could be displayed on a series of maps. After all, planners understood and worked with maps. Furthermore, such maps could be kept in the county planning office for reference by any developer or interested person. In 1971, the CSFS hired consultant George Fahnestock to help develop such a mapping technique[1]. It became known as the Wildfire Hazard Area Map (WHAM) system (Zeleny 1974; Tom and Getter 1975; Getter 1976; Seger and Frobig 1976). The CSFS soon began to map priority areas and also to train county planning staffs to do mapping. Over 5.2 million ha of forested lands subject to development have been mapped.

In Colorado, local officials make final decisions on proposed land uses and the subdivision standards. Education of those officials dealing with wildfire safety became another major effort. Similar activities were also initiated with state officials, particularly key legislators and the staff of the state's Land Use Commission (now defunct).

The 1970s saw two important pieces of new state legislation passed that helped the wildfire safety and protection of subdivided areas. The first, Senate Bill 35 (1972), mandated that all counties adopt and publish a set of subdivision regulations for that county. It also established plan review procedures and mandated that all counties send copies of proposed subdivision plans to the state forester for review and comment prior to the plan hearing. Plan reviews became a major work activity for the CSFS. More forestry personnel were requested and authorized by the legislature to do this work. Plan reviews continue to this day as an important part in the overall provisions for wildfire safety, fire prevention, and fire protection in Colorado. The second piece of state legislation, House Bill 1041 (1974), enabled counties to designate areas of special concern such as fire hazards and mandated the state forester to develop guidelines for managing such designated fire hazard areas. Although the guidelines were developed and distributed, no wildfire hazard areas have ever been designated by a county—probably due to the local politics of placing such a label on private land.

Starting in 1970, the thinking and implementation of other forest land management practices, such as forest management and insect control, were modified to keep fire in mind. This has continued to today.

Using a grant from the U.S. Forest Service in 1971, a 16-mm color film entitled *Design for fire* was developed to help county officials visualize the subdivision wildfire problems and solutions. Forest service publications and other visuals also followed; some were entirely new, and others were modified to incorporate fire as a concern (Colorado State Forest Service 1974; Lynch 1975; Coulter 1980; Dennis 1983; Zeleny 1988). The publications were aimed at three distinct groups of users: local officials, developers and foresters, and homeowners. A pamphlet, initially produced in 1979, entitled *Your forest home... protect it from fire*, has been very popular.

Organization of local, state, and federal fire suppression forces was another item that needed work. The old, traditional way of organizing for wildfires did not work well for multiple agencies who were trying to protect both wildlands and structures at the same fire. After much looking at other methods, the Colorado Incident Command System (CICS), which was tailored closely after the national Incident Command System (ICS) was begun in 1981. It fit many of the non-wildland incident needs of local fire departments in both rural areas and municipalities. Only slight modifications were required for CICS to fit the later national ICS model. All state, federal, and several county wildland and local fire agencies completed their adoption of the new system in 1984, a full 2 years ahead of the national schedule for the U.S. Forest Service. The CICS Board continues today to guide CICS implementation statewide for all risks, not just wildfire. Additional local agencies now have adopted CICS including many law enforcement agencies so critical to traffic control and evacuations in interface fire incidents. A pamphlet describing the CICS has been prepared.

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[1] Fahnestock, G.R. 1971. Rating forest-fire hazard in residential developments in Colorado forests. Univ., Colo. State For. Serv., Fort Collins, Colorado. Unpubl. Rep.

Working together with other agencies was found to be the best approach to solving the interface fire problem. All could benefit from each partner agency's strength, giving the total effort maximum strength at low cost. Some of the other joint efforts have been mixing state and federal employees on wildfire overhead teams; interagency funding of the two federal fire centers; and state-county agreements encouraging initial-attack fire aircraft use and sharing its costs.

By 1986, the land-use planning and plan review process needed strengthening due to changes in state forestry and county personnel over the years. The activity was reinforced through emphasized state forestry objectives in 1987 and 1988. A workshop sponsored by the Colorado wildland agencies entitled, "Protecting people and homes from wildfire in Colorado" was held May 18, 1988, in Denver for local officials to renew wildfire awareness. Over 75 federal, state, county and city foresters, commissioners, planners, fire officials, and several land developers attended. It proved that once achieved, awareness must be constantly maintained.

In conclusion, Colorado has made some good progress in the protection of people and their developments from wildfire. Much of the success can be attributed to an early awareness and a commitment to a long-haul approach. A quick fix has not been Colorado's method; a holistic approach that involves all forestry activities and all levels of government has been a guiding principle. But our work is not finished. Wildfire losses and acres burned continue to rise. Colorado does not intend to rest on its good accomplishments of the past to meet the challenges and opportunities of tomorrow.

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INTERAGENCY COOPERATION DURING A SEVERE MULTIPLE WILDFIRE SITUATION

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ABSTRACT

This paper represents a problem analysis dealing with the present and future direction of interagency cooperation during day-to-day operations in severe multiple wildfire situations in the Northern Rocky Mountain region of the United States, particularly within Montana and Yellowstone National Park. The 1988 summer fire season exemplified the need for close interagency cooperation and communication. The work of the Northern Region Coordination Group, formed in 1984 to implement the Incident Command System (ICS) on an interagency basis in northern Idaho, Montana, and North Dakota, is outlined. Joint fire planning and the use of interagency dispatch centers streamlined the suppression efforts in 1988. Multiagency Coordination Groups (MAC) were set up early to relieve dispatch and incident management teams of the responsibility for making key decisions regarding the sharing and use of critical resources and prioritizing incidents. The Montana incident coordination organization in Missoula monitored and provided information on resource status, incident situation status, fire weather, fire behavior predictions, fiscal issues, political problems, and safety concerns. These interagency efforts and the 1988 wildfire season has become the new benchmark year against which fire scope, fire policy, and fire behavior severity will be measured.

INTRODUCTION

The 1988 wildfire season has become the new benchmark year against which fire scope, fire policy and fire behavior severity will be measured. The terms "let burn", "residential-wildland interface", and "interagency cooperation" will take on a new vigor in the months to come. Before we can discuss the scope and magnitude of the fire season and cooperative efforts, we must first understand the scope and magnitude of Montana.

BACKGROUND

Montana, the fourth largest state, is 885 km long, 440 km wide, and encompasses 38 million ha. The western one-third is primarily timbered mountainous terrain where recreation and forestry are the main industries. The central one-third consists of isolated mountains and plains, and the eastern one-third is plains country with farming, ranching, and mining being the main industries. Montana's fire protection is handled by 375 city, rural, and volunteer fire departments, 10 national forests, seven Indian reservations under the USDA Bureau of Indian Affairs, three USDI Bureau of Land Management districts, Glacier National Park, the northern portion of Yellowstone National Park (YNP), and the Montana Department of State Lands. To further complicate fire protection matters, there has been in the last 15 years a dramatic increase in the number of structures built within Montana's wildlands. We are all witnesses to this rapidly expanding residential-wildland interface, and the 1988 fire season exemplified its magnitude and interagency ramifications.

THE 1988 MONTANA FIRE SEASON IN SUMMARY

The 1988 fire season wasted no time in getting started with the Whitehall Fire on February 21, which consumed 485 ha and 39 structures in southwestern Montana. Lack of winter snowpack and minimal spring rains just added to the region's drought condition. By mid-June over 40 000 ha had already burned in eastern Montana. Severe fire behavior had trapped several fire fighters, and at least three fire fighters received extensive burns. By July 15, western Montana and YNP were experiencing problems. Fuel moistures were so low in all roundwood diameter size classes that the large timber fuels were carrying the fire and not the normal fine grass fuel component.

Fires behaved in reverse of normal summer expectations. Daytime inversions caused fires to lay down until late afternoon or even dark. But with the clearing of smoke, fires, especially at midslope, became very active and burned violently throughout the entire night. Fire growth through readily repeated cycles of torching and long-distance spotting was also very evident. Daytime inversions made aircraft operations very marginal, and with night's fire activity, safety of fire-fighters was paramount.

By September 10, 2720 fires had burned more than 358 550 ha within the state of Montana. This area burned doesn't include the mammoth fires in YNP that burned roughly 0.45 million ha. The international mobilization far exceeded any other operation, including last year's record fires in California and Oregon. By late August and early September approximately 16 000 fire-fighters were on the lines. Canadian, federal, state, county, and city fire-fighters were aided by six battalions of regular U.S. Army and two battalions of U.S. Marines. By late summer U.S. President Ronald Reagan approved the use of Canadian fire suppression forces on U.S. fires. This precedent began its way through the U.S. Congress last winter after the California and Oregon fires. The forestry and construction industry provided heavy equipment. The multiagency effort involved a total of 18.2 million litres of retardant from 45 air tankers and 96 helicopters. At the peak, 448 engines were utilized from all over the U.S. This is not to mention several other items such as the 805 km of hose deployed or the 181 000 garbage can liners used or the 862 million kg of other supplies used.

Coordination of activities at times became quite hectic, especially when for the first time at this level we became deeply involved in area closures, evacuations, and major power and phone outages. The fires in Montana cost an estimate of $U.S. 68 million and in YNP another $U.S. 109 million and daily suppression expenditures averaged over $U.S. 1 million.

Two fire-fighters lost their lives in Montana while on duty. Well over 100 structures were lost, and thousands were saved by the efforts of many heroic fire-fighters in the residential-wildland interface. During such a severe wildfire situation, a key to success was close interagency cooperation among all levels of the fire and emergency services.

INTERAGENCY OPERATIONS

Interagency cooperation doesn't come overnight, and levels of trust and cooperation are built through time by individuals taking the bull by the horns and moving forward to accomplish the task at hand. The first major move with interagency cooperation in Montana was with the formation of the Northern Region Coordination Group in 1984. This group covers northern Idaho and Montana. The group's membership includes the U.S. National Park Service, Montana State Office of the Bureau of Land Management, Portland and Billings offices for the Bureau of Indian Affairs, U.S. Forest Service—Region 1, Idaho Department of Lands, Montana Department of State Lands, and Montana's Division of Disaster and Emergency Services. The goals of the group are twofold: 1) to further interagency cooperation, communications, and coordination involving fire-related activities, and 2) to identify opportunities for increased efficiency and improved coordination. The Northern Region Coordination Group's first major task was to implement the Incident Command System (ICS). Subcommittees on communications, training, equipment, prevention, cache support, and dispatching support were formed to coordinate the ICS implementation.

The communications subcommittee has worked on the issue of frequency sharing between agencies. The training committee annually prepares an interagency curriculum to meet all agency ICS training needs. Training costs and instructors are provided by participating agencies, and training is done on an interagency basis. This includes interagency overhead teams. The prevention committee is addressing the wildland-residential interface issue and various interagency measures to mitigate our problems in the interface. The dispatching and support committee has formulated a plan to aid and supplement incident dispatching and support needs.

Montana and northern Idaho have been divided into geographic zones to address fire support and suppression needs. Not all agencies have agreed on exact boundaries or intent but they have agreed on the concept. If the concept is to become reality, it must be planned and implemented at the local level. For example, in 1988 northwestern Montana began implementing their agreed-upon alternative. This zone consists of Glacier National Park, the Flathead National Forest, the Kootenai National Forest, and the Northwestern Land Office of the Montana Department of State Lands.

In the spring of 1988, a joint interagency dispatch center was established in Libby, Montana, between the Montana Department of State Lands and the Kootenai National Forest. In time, support to this center will come from a zone facility in Kalispell. As the plan evolves, support needs will be provided from within the zone until resources are exhausted to a preplanned level. Additional orders will then be processed through either the state or regional coordination center. The regional coordination center is then tied to the national interagency fire center in Boise, Idaho, for resources unavailable in the state of Montana or adjoining areas.

As numbers of wildfires, complex incidents, and the involvement or impact on other agencies increases as it did early in 1988, it is necessary to expand day-to-day coordination and management organizations to insure efficient and effective use of critical resources. This is not an expansion of the ICS but rather an expansion of the coordination and management system that supports on-the-ground incident management organization(s). This expansion of the coordination and management system has been termed MAC or Multiagency Coordination group; MAC groups can be placed at the national, regional, and local levels. An MAC organization represents the agencies of which it is composed. In 1988, the Northern Region MAC representatives included the U.S. National Park Service, Bureau of Land Management, Bureau of Indian Affairs, U.S. Forest Service, Idaho Department of Lands, and Montana Department of State Lands. Agency representatives tivesare brought together and briefed by an incident coordination organization so that they can relieve dispatch and incident teams of the responsibility for making key decisions regarding the sharing and use of critical resources and prioritizing incidents. The MAC organization does not operate directly with the incident command or area command authority who have responsibility for the management of the on-the-ground incident organizations. The flow of information is from MAC through expanded or normal dispatch channels.

A Regional Incident Coordination Organization (RICO) was established in Missoula, Montana, from July 23 to September 17, 1988. The group monitored and provided information on resource status, incident situation status, fire weather, fire behavior predictions, fiscal issues and safety concerns. Geographically, the Missoula MAC group covered North Dakota, Montana, northern Idaho, and YNP. Due to the complexities of Yellowstone and surrounding areas a Unified Area Command structure was established in West Yellowstone, Montana, which worked with the MAC organization. Briefings were held daily at 10:00 a.m. and 5:30 p.m. Following the briefings the MAC team met to prioritize incidents, resolve issues, and recommend forest activity restrictions or closure levels. As resources became critical, incidents increased in magnitude—evacuations were ordered and general forest closures were discussed. Washington office personnel from the Boise Interagency Fire Center became involved, and even the Governor of Montana was present at daily briefings. The RICO ran for 63 days during the summer of 1988, addressing numerous interagency political and management issues on over 50 project incidents. Similar multiagency coordination groups were set up to address local concerns and needs. This was especially true in residential-wildland interface areas where close coordination and prioritization was required between wildland protection agencies, structure protection agencies, law enforcement, disaster and emergency services, and local government. These groups worked well for the most part in reaching consensus decisions on critical issues. In areas or on incidents that did not address the local jurisdictions and needs through interagency involvement, the political problems are now just beginning to surface and spark.

THE COOK CITY INCIDENT IN REVIEW

I would now like to review one of the 2700 incidents from 1988 in which interagency cooperation greatly assisted in protecting two Montana communities from wildfire.

About 6.4 km east of the northeast entrance to YNP lies Cooke City, a sleepy community of approximately 250 inhabitants. In between Cooke City and the park entrance is the town of Silver Gate, population 150. Both unincorporated communities fall under Park County Rural Fire District #7-Cooke City. Landowners can augment their wildland fire protection through the Montana Department of State Lands, who assigns the Gallatin National Forest as the lead protection agency.

Cooke City's water supply consists of a 113 550-L gravity-fed system, which supplies six hydrants in the town. Silver Gate has no developed water supply system for fire fighting. Soda Butte Creek does, however, run through both communities, offering a natural source of water.

Local inhabitants remember that the last significant fire responded to by the Cooke City Rural Fire Department was 7 years ago, but this summer eliminated that statistic. Dry lightning on July 9 started the Mist Fire, and on July 11 the Clover Fire. Both fires were allowed to burn in YNP, 24 km south of Cooke City and Silver Gate. These two fires joined on July 22 to form the Clover-Mist Fire, which continued to grow and advance on the two Montana communities. By September 14, Clover-Mist had covered 167 291 ha and on two occasions in August came within 1.5 km of Cooke City and Silver Gate, stopping only at the rocky Republic Pass divide. These runs by Clover-Mist alerted the residents to call for several public interagency meetings. Many questions were asked about their level of fire protection and what individual owners could do in and around their homes to protect them from wildfire. As the towns watched the Yellowstone fires to the south, the real danger was to the north. The Storm Creek Fire, another lightning-ignited fire started on June 14 in the Absaroka-Beartooth Wilderness, slowly began a march south toward the two towns. The Storm Creek Fire crossed three major topographic barriers, and on September 1 it spotted into the Soda Butte drainage. Fuels in the drainage are continuous and heavy with a high spotting potential.

Another dry, cold front with strong westerly winds was predicted to arrive over the fire area on Tuesday, September 6 and to continue through Friday. This would push the fire up Soda Butte drainage, threatening both communities. With no natural or manmade barriers to impede the fire from reaching these two towns, numerous plans went into effect to protect the communities. Park County Disaster and Emergency Services, the local sheriff's department, and county commissioners prepared a house-by-house evacuation and security plan in conjunction with the Montana Department of State Lands and the national type 1 interagency team managing the Storm Creek incident. On Saturday, September 3, the Storm Creek command team placed an order for five strike teams of structure type 1 and 2 engines.

All but two of the 25 engines were filled from 20 different Montana fire departments through cooperative agreements the State has with the counties. These structure engines were supplemented by another 30 wildland engines, handcrews, bulldozers, and helicopters, which brought the towns' population to well over 1000 inhabitants. The Yellowstone Unified Area Command and the Missoula MAC group placed a number-one priority on resource orders for the Storm Creek Fire.

On September 4, a burnout was ignited between Silver Gate and the park entrance on a preconstructed dozer line with the objective of creating a 3-km buffer between Silver Gate and the approaching Storm Creek Fire. In preparation for Tuesday's front, fire fighters prepared preplans on all key structures and tested water supplies. Water supply systems were established in both communities. In Silver Gate two 3.8 million-L dams were created in Soda Butte Creek with two engines supplying water. Large (12.7-cm diameter) supply lines and portable hydrants branching to smaller (6.35-cm and 7.62-cm diameter) lines were established, which were boosted by engines as necessary. In Cooke City, two type 1 engines were placed at Soda Butte Creek to act as fill site engines for water tenders and wildland fire engines. One engine supplied a 300-m line (11.4-cm diameter); this line was boosted, and smaller (6.35-cm diameter) supply lines were relayed through five attack engines or master stream devices down the entire length of the main street in the community. This system was augmented by portable pumps supplying auxiliary lines. In remote locations water tenders and fold-a-tanks supplied engines.

On Sunday, September 4, residents were asked to evacuate. Montana State Highway Patrol, Wyoming Patrol, and Park County sheriff personnel closed Highway 212. On Labor Day, September 5, dozer lines were constructed on the northern edges of each town. On Tuesday morning, September 6, with the arrival of a frontal passage in western Montana, county commissioners declared a disaster, and full evacuation was ordered. At 5:00 p.m. winds increased to 25-40 km/h with gusts of 50 km/h. Relative humidity was 16%, and at approximately 6:00 p.m. a spot fire was discovered on the middle one-third of the north slope above Silver Gate. The spot was inaccessible to engines and quickly reached 20 ha in spite of the immediate action of dozers and the efforts of two helicopters dropping water within minutes of the fire's discovery. The fire paralleled the north edge of Silver Gate throughout Tuesday night. The smaller 4 × 4 wildland fire engines patrolled the dozer line with handcrews to stop any spot fires from crossing the line. Larger structural engines foamed structures and patrolled areas for burning embers on roof tops and between structures. Helicopters cooled hot spots around power and telephone poles and provided spot fire reconnaissance.

By midmorning Wednesday (September 7), the firestorm reached and again paralleled Cooke City's northern edge. By day's end the Storm Creek Fire had passed both cities with no structure loss. On Wednesday evening the fire moved into the Colter Pass area and over the Wyoming state line. Here the fire destroyed one permanent residence, five summer cabins and one sawmill shop. On September 8, residents were allowed to return to their residences while fire fighters mopped-up. In closing, this is one example of how interagency cooperation helped prevent serious loss during the 1988 fire season in Montana.

THE AUTHOR

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INTERNATIONAL MUTUAL AID IN WILDLAND FIRE-FIGHTING: WHAT'S HAPPENING ON THE U.S.-CANADA SCENE?—AN UPDATE

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This paper briefly reviews the history of the U.S.-Canada Agreement for Wildland Fire Assistance and what has occurred since its implementation in 1982.

Meetings of wildland fire-fighting agency personnel from the United States and Canada in the mid 1970s identified the need for an agreement to cover all forms of mutual assistance in fighting forest fires. The efforts of both governments through formal channels resulted in an exchange of diplomatic notes between the two governments authorizing mutual aid fire-fighting assistance on May 4, 1982.

Each year since the agreement was implemented, personnel from each country have met to review and modify the annual operating plan[1]. This has allowed the sharing of wildfire situation information and established formal contact points between the two countries. Also each year the U.S. has provided assistance to Canada in the form of pumps and hose, infrared aircraft, ground suppression crews, smoke jumpers, and overhead teams (Drysdale 1979). The assistance that has been provided under the terms of the agreements since the inception of the mutual aid arrangement in 1982 is summarized in Table 1.

Existing U.S. legislation has prohibited U.S. federal government agencies from reimbursing Canada or other foreign governments for assistance. Each year, beginning in 1984, legislation has been introduced in the U.S. Congress to allow for the reimbursement of wildland fire-fighting assistance. In 1988, during the severe wildfire activity in the western United States, the U.S. Congress passed emergency legislation temporarily allowing reimbursement for mutual assistance until December 31, 1988. Canada provided a variety of fire suppression resources:

- 12 air tankers, including two CL-215 skimmer aircraft plus eight air attack aircraft for "bird-dogging";
- one infrared aircraft;
- 144 personnel (124 for helicopter support and 20 for waterhandling); and
- supplies amounting to 3895 Pulaskies and 200 Mark III pumps.

There is currently (fall of 1988) an attempt in the U.S. Congress to provide permanent authority to reimburse any foreign government for their assistance in wildland fire-fighting. The U.S. Senate version of the legislation did not get through the Agriculture Committee due to additional legislation being attached to the proposed bill. It is anticipated that a new attempt will be brought forth during the next legislative session to provide for a permanent arrangement. The numerous local mutual aid agreements along the U.S.-Canadian border that have been in effect for many years now are not affected by the temporary 1988 agreement or by the proposed legislation.

REFERENCE

Drysdale, R.J. 1979. Mutual aid and Ontario. Pages 15-16 *in* D. Quintilio, compiler. Proceedings of the international fire management workshop. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-215.

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[1] Representation from the Canadian Interagency Forest Fire Centre (CIFFC) at Winnipeg, Manitoba, and the National Interagency Fire Coordination Centre (NIFCC) located at the Boise Interagency Fire Center (BIFC) at Boise, Idaho.

Table 1. Summary of assistance provided to Canada under the terms of the Canada-United States arrangement for fire-fighting assistance since the inception of the agreement on May 4, 1982

Fire	Sending	Receiving	Resource(s)	
season	unit	unit	Item	Quantity[a]
1982	Alaska Fire Service (BLM)[b]	Yukon Territory	Class II overhead team	1
			Ground suppression crews (16 persons)	16
	BIFC[c]	Yukon Territory	Infrared aircraft	1
			Radio equipment	NA
			Crew transport aircraft	1
1983	BIFC	Quebec	Infrared aircraft	1
		Ontario	Infrared aircraft	1
		Manitoba	Radios	NA
			Fire protective clothing	NA
			and climbing gear	NA
1984	USDA Forest Service (R-6)	British Columbia	Smoke jumpers	NA
	Alaska Fire Service (BLM)	Yukon	Overhead team members,	NA
			ground suppression crews,	NA
			and smoke jumpers	NA
1985	BIFC	British Columbia	Hose and accessories	14 118 kg, 31 m^3
1986	BIFC	Manitoba	Basic fire training instructors	3
			Infrared aircraft and crew	1
1987	BIFC and USDA Forest Service (R-6)	Ontario	Pumps and hose	44 693 kg, 120 m^3
	USDA Forest Service (R-1)	Ontario	Pumps and hose	16 141 kg, 40 m^3
1988	BIFC	Ontario	Pumps and hose	9 173 kg, 29 m^3
			Radio system	NA
	USDA Forest Service (R-1)	Ontario	Pumps and hose	7 355 kg, 44 m^3
	USDA Forest Service (R-4)		Ground suppression crews	2
	USDA Forest Service (R-6)		Pumps and hose	3 428 kg, 12 m^3
			Type I overhead team	1
			Ground suppression crews	7

[a] NA = not available. [b] BLM = Bureau of Land Management. [c] BIFC = Boise Interagency Fire Center

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NEAL HITCHCOCK is a Logistics Coordinator with the USDA Forest Service at the Boise Interagency Fire Center in Boise, Idaho. He received a B.Sc. degree in natural resources from Ohio State University (1977). Neal has worked in various positions with the U.S. Forest Service beginning in 1976 on the Toiyabe National Forest in Nevada. He assumed his present position in 1987.

PREVENTION OF RAILROAD-CAUSED WILDFIRES IN NEBRASKA

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ABSTRACT

This paper takes a look at the relationship between the railroads operating in Nebraska and railroad-caused wildfires. Actual causes of railroad fires, while often hard to determine, provide important insights into preventing wildfires. Time, economics, and regulation have an important impact on how railroads operate and also on how and to what extent they cause wildfires. The political and agency environment plays an important role in determining how to approach the railroad fire problem. In Nebraska, the approach has been less on regulation and more on building cooperative programs and relationships with a particular emphasis on information sharing.

INTRODUCTION

In the United States less than 5% of all wildfires are started by railroads. By contrast, in Nebraska, about 25% of all wildfires are railroad-caused. In some years railroad fires rank first and rarely have they ever ranked below second in terms of total annual number of wildfires in Nebraska. Large railroad fires are the exception rather than the rule, but other circumstances can make them particularly troublesome. Multiple fires are common and inherent to the problem because some system has failed or is malfunctioning. It is not unusual to have fires strung out over several miles of right-of-way. Railroad fires occur in clusters. Over a year's time many fire districts will not have any railroad fires while other districts (with similiar trackage) will be overwhelmed by railroad-caused wildfires. Another problem arises from the need to drive over and along rights-of-way, tracks, and ties. This causes a great deal of damage to fire equipment. For a variety of reasons attention must be given to the prevention of wildfires caused by railroads.

RAILROAD INDUSTRY BACKGROUND AND CHANGES

The railroad operations of yesterday were quite different from today's operations. Just as change has impacted railroad operations so also has it impacted the way wildfires are caused by railroad operations. Turbo-charged locomotives have, for the most part, replaced normally aspirated locomotives. Normally aspirated locomotives had the need for spark arrestors at the terminal end of the exhaust stream to trap glowing carbon particles. Turbo-chargers have rapidly spinning vanes in the exhaust stream that pulverize these carbon particles to the extent that they are recognized as spark arrestors. Railroads have more and more selected turbo-charged locomotives as replacements for normally aspirated models. Industry-wide, the percentage of locomotives that are turbo-charged is about 70%.

Generally speaking, the newer, more efficient turbo-charged power units are used in long haul, main-line situations. In this application the percentage of power units that are turbo-charged is probably 80-85%. The widespread implementation of turbo-charged units has doubtless resulted in fewer wildfires caused by carbon particles. The problem hasn't disappeared, but it has changed. Turbo-charged locomotives have their crankcases ventilated through eductor tubes. Carbon can build up on the inner surfaces of these tubes. If allowed to accumulate, it will eventually flake off and be discharged (glowing) from the locomotive. The solution now is the regular inspection and cleaning of these eductor tubes. Fires caused by sparking brake shoes have been nearly eliminated by the advent of brake shoes made of new materials that are nonsparking. Stuck brakes and dragging equipment continue to be a problem, though, and are often confused for sparking brake shoes.

Modern technology has replaced the axle journal and bushing with a sealed roller bearing. Since the old journal boxes are so rare, so also are the "hot boxes" that were once a troublesome cause of wildfires.

The most recent and obvious change in railroad operations is the removal of cabooses. In many instances trains are operating with end-of-train devices rather than cabooses. This change has probably had an impact on wildfire ignitions because fusees, dropped from cabooses to warn following trains that the train ahead is in trouble, are no longer being used in this fashion. Some fusee use continues but to a lesser degree than in the days of cabooses. Some would argue that without cabooses, some fires are not being reported as promptly as they used to be. There have been cases of conductors radioing in the locations of fires started presumably by his train. How often this happened is unknown but was likely very infrequent.

Some fire causes remain unchanged. Use of fusees by track crews continues, and the potential for wildfires remains when the fusees are misused. Track maintenance operations, such as welding, grinding, and sawing rails, continue to be troublesome causes of wildfires.

NEBRASKA BACKGROUND

In 1972 a meeting was organized between members of the Nebraska Stock Growers Association, state senators, railroads, volunteer fireman's associations, state forestry personnel, the state fire marshal's office, state civil defense, and the U.S. Forest Service. The result of the meeting was a set of eight guidelines. These were voluntary guidelines, agreed upon by all present at the meeting. The suggestion at the time was that if these flexible, voluntary guidelines did not reduce the number of railroad-caused wildfires, then legislation and regulation were sure to follow. Here, in summary form, are the eight points agreed upon:

1. Specifications given for spark arrestors.

2. Inspection intervals and maintenance of spark arrestors.

3. State forester will receive fire reports and document problem areas. Survey parties will visit areas and discuss remedial actions.

4. Established procedures for stopping a train that is causing fires.

5. Railroad to supply state forester and state fire marshal with their policy for burning along rights-of-way.

6. Railroads to send instructions for proper use of fusees to local train crews.

7. Local fire departments to supply as much detail as possible about railroad fire causes on fire reports.

8. The main purpose of these guidelines is to reduce the number of railroad-caused wildfires. If this doesn't happen then a plan should be devised for the railroads to compensate local fire departments for person-hours and equipment used in fighting railroad fires.

These guidelines were purposely designed in a general way so that railroads would not be restricted from using new technology as it became available.

Since 1972 the number of railroad fires has shown normal fluctuation (depending upon the severity of the fire year) but basically has remained constant. During this same time period the number of tonne-kilometres moved by the railroad companies operating in Nebraska has increased markedly. Previewing these two pieces of information, it would appear that some success was achieved in preventing railroad-caused wildfires. It should be noted that even though railroads have made improvements resulting in fewer wildfire starts, improvements have been made elsewhere as well, resulting in fewer wildfire starts by other causes. This fact makes it harder for railroads to change their position in the ranking of major fire causes.

Even though the number of railroad-caused wildfires per tonne-kilometre have decreased, fires continue to be caused by railroads. Some of these fires are noticed more than others. On March 3, 1985, a 1620-ha railroad-caused fire burned near the Sandhills ranch of a Nebraska state senator. Since that time, the senator has pursued legislation to regulate railroads in the state although none has passed to date. The Nebraska Forest Service has been involved only marginally. In fact, the agency's only involvement at a public meeting has been at the request of the railroads. The agency keeps records of wildfires and has supplied the senator with the same monthly and annual reports that are sent to the railroads. This cooperation will continue as requested. The Nebraska Forest Service hopes to have input into legislation if it is forthcoming.

Even though the Nebraska Forest Service amasses wildfire reports and statistics it has no regulatory powers. The Public Service Commission and the state fire marshal's office do have these powers and have been more involved in this issue.

THE NEBRASKA APPROACH

As mentioned earlier, the Nebraska Forest Service is not a regulatory agency; therefore, the approach has been more through the channels of information and education. The agency has promoted the use of hazard reduction. It is possible to identify stretches of right-of-way that have high fire occurrence. For many years railroads were conducting hazard reduction burning along these stretches. In recent years this activity has lessened, apparently in an attempt to keep costs down. In some cases alternatives to burning (such as mechanical and chemical removal) have been utilized.

Perhaps our greatest strength is our ability to provide the railroads with meaningful information about wildfires. Annually we publish *Nebraska Wildfires*, a publication of wildfire statistics and analysis that covers the past year as well as the previous 5 years. Each of the major wildfire causes (including railroads) is given individual attention with an analysis of the data, maps, and occurrence patterns through the months. Perhaps more important than this publication, a monthly update of wildfires is mailed to officials of each railroad (Fig. 1). It shows the date and time of the fire, the area burned, and the damage to improvements, as well as listing the fire district and county where the fire took place. Finally it lists the railroad company that started the fire. This update helps the Nebraska Forest Service and the railroads see the extent and locations of railroad fire problems as they develop. For a number of years, information about the wildfires started by a particular railroad was sent only to that railroad. This meant that each railroad received information only about the wildfires for which they were responsible. Now the agency has started sending a complete set of railroad-caused wildfire statistics to each railroad. This means that a railroad company not only sees the wildfires it starts but also the wildfires started by the other lines operating in the state. This has resulted in considerable peer pressure between the railroads. Now railroads (those with better fire records) have started pressuring other railroads (those with poorer records) to do a better job of fire prevention. The first step in solving a problem is an awareness of the problem. This information program is our way of establishing and maintaining an awareness of the railroad-caused wildfire problem.

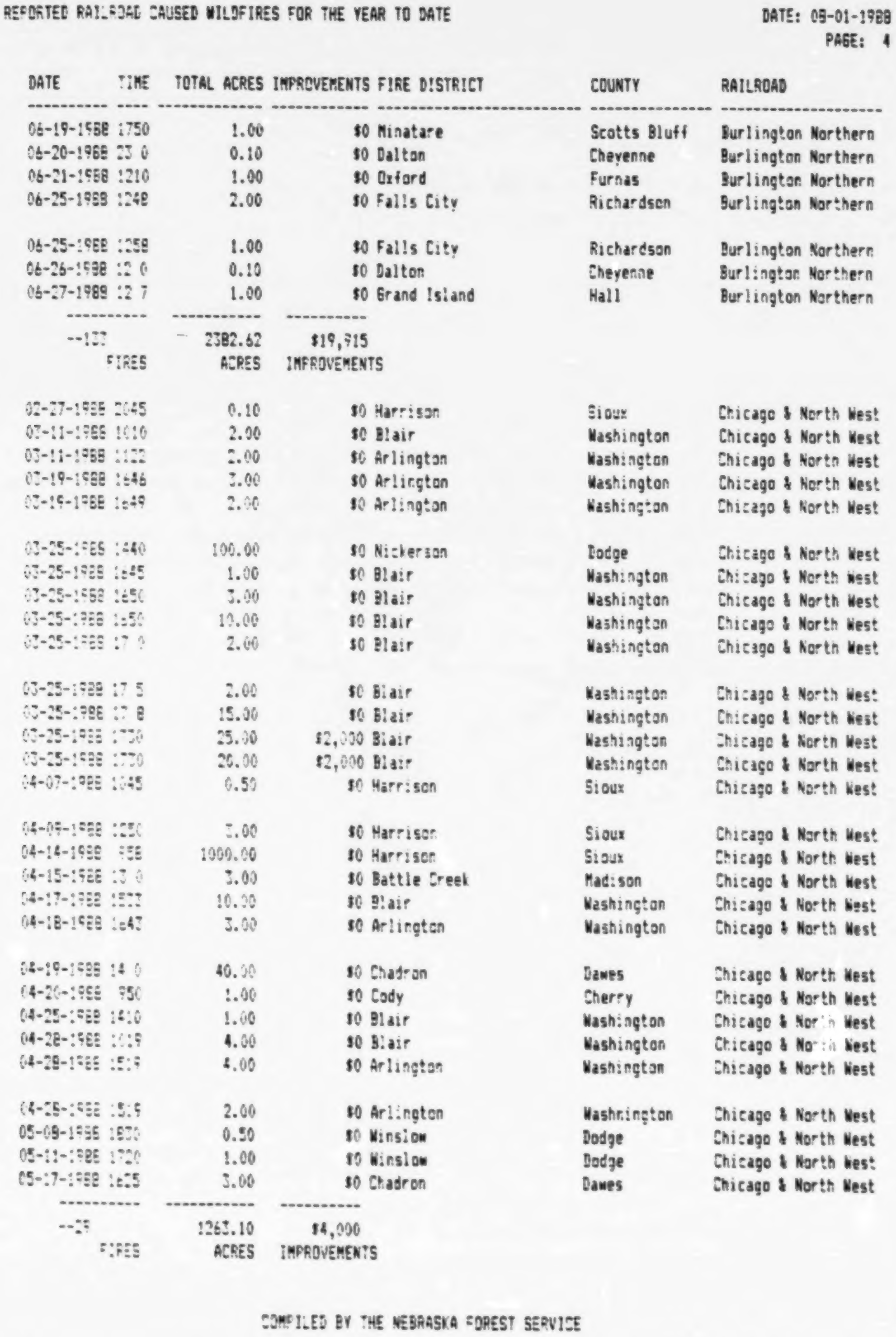
Maintaining good working relationships with both the railroads and firemen of the state has always been a top priority. Through the years it has become natural and second nature to pick up the phone and visit with people from either the railroads or fire departments. This helps to keep small problems from growing into large ones. It has also helped us facilitate meetings between fire fighters and railroads. Indeed, the preparing of this paper was made easier by just this sort of relationship. We are friendly with each group of principals in the railroad fire problem, and each group is confident that we will fairly represent and communicate their concerns to the other.

The possibility of additional regulation of railroads exists in the coming years. Whether this will happen or not is uncertain at this time—last year's efforts died in committee. If legislation is passed, our hope is that the regulations will be tempered with the reality of the present situation. Regulations that are too severe will be resisted by the railroads. To be effective, regulations must be aimed at specific fixes to specific problems that cause fires. These fixes must also be reasonably attainable by the railroad. One concern that the railroads have about state regulation is the need for a national perspective. Since railroads travel through so many states, having to comply with a different set of rules in each state would increase operating costs.

National standards drawn up with a national perspective would probably benefit most states with a railroad wildfire problem. Standards like this, if adopted by Nebraska, would have the national perspective needed by the railroads and would probably also please the fire fighters of the state.

THE AUTHORS

DON WESTOVER is the Fire Coordinator for the Nebraska Forest Service (NFS), which is headquartered



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REPORTED RAILROAD CAUSED WILDFIRES FOR THE YEAR TO DATE                                       DATE: 08-01-1988
                                                                                                    PAGE:  4

  DATE       TIME  TOTAL ACRES IMPROVEMENTS FIRE DISTRICT              COUNTY         RAILROAD
  ---------- ---- ------------ ------------ ------------------------- -------------- -------------------
  06-19-1988 1750         1.00           $0 Minatare                  Scotts Bluff   Burlington Northern
  06-20-1988 23 0         0.10           $0 Dalton                    Cheyenne       Burlington Northern
  06-21-1988 1210         1.00           $0 Oxford                    Furnas         Burlington Northern
  06-25-1988 1248         2.00           $0 Falls City                Richardson     Burlington Northern

  06-25-1988 1258         1.00           $0 Falls City                Richardson     Burlington Northern
  06-26-1988 12 0         0.10           $0 Dalton                    Cheyenne       Burlington Northern
  06-27-1988 12 7         1.00           $0 Grand Island              Hall           Burlington Northern
       ----------   -----------   ----------
       --133        -  2382.62      $19,915
            FIRES         ACRES   IMPROVEMENTS

  02-27-1988 2045         0.10           $0 Harrison                  Sioux          Chicago & North West
  03-11-1988 1010         2.00           $0 Blair                     Washington     Chicago & North West
  03-11-1988 1122         2.00           $0 Arlington                 Washington     Chicago & North West
  03-19-1988 1646         3.00           $0 Arlington                 Washington     Chicago & North West
  03-19-1988 1649         2.00           $0 Arlington                 Washington     Chicago & North West

  03-25-1988 1440       100.00           $0 Nickerson                 Dodge          Chicago & North West
  03-25-1988 1645         1.00           $0 Blair                     Washington     Chicago & North West
  03-25-1988 1650         3.00           $0 Blair                     Washington     Chicago & North West
  03-25-1988 1650        10.00           $0 Blair                     Washington     Chicago & North West
  03-25-1988 17 0         2.00           $0 Blair                     Washington     Chicago & North West

  03-25-1988 17 5         2.00           $0 Blair                     Washington     Chicago & North West
  03-25-1988 17 8        15.00           $0 Blair                     Washington     Chicago & North West
  03-25-1988 1730        25.00       $2,000 Blair                     Washington     Chicago & North West
  03-25-1988 1730        20.00       $2,000 Blair                     Washington     Chicago & North West
  04-07-1988 1045         0.50           $0 Harrison                  Sioux          Chicago & North West

  04-09-1988 1250         3.00           $0 Harrison                  Sioux          Chicago & North West
  04-14-1988  958      1000.00           $0 Harrison                  Sioux          Chicago & North West
  04-15-1988 13 0         3.00           $0 Battle Creek              Madison        Chicago & North West
  04-17-1988 1533        10.00           $0 Blair                     Washington     Chicago & North West
  04-18-1988 1643         3.00           $0 Arlington                 Washington     Chicago & North West

  04-19-1988 14 0        40.00           $0 Chadron                   Dawes          Chicago & North West
  04-20-1988  950         1.00           $0 Cody                      Cherry         Chicago & North West
  04-25-1988 1410         1.00           $0 Blair                     Washington     Chicago & North West
  04-28-1988 1019         4.00           $0 Blair                     Washington     Chicago & North West
  04-28-1988 1519         4.00           $0 Arlington                 Washington     Chicago & North West

  04-28-1988 1519         2.00           $0 Arlington                 Washnington    Chicago & North West
  05-08-1988 1830         0.50           $0 Winslow                   Dodge          Chicago & North West
  05-11-1988 1720         1.00           $0 Winslow                   Dodge          Chicago & North West
  05-17-1988 1625         3.00           $0 Chadron                   Dawes          Chicago & North West
       ----------   -----------   ----------
       --29            1263.10       $4,000
            FIRES         ACRES   IMPROVEMENTS


                         COMPILED BY THE NEBRASKA FOREST SERVICE
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Figure 1. An example of the monthly update of wildfires prepared by the Nebraska Forest Service.

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ROGER FITCH is Manager, Fire Protection for Union Pacific Railroad Company in Omaha, Nebraska. He was born and raised in Portland, Oregon. Roger received his B.Sc. degree from Stanford University. He worked for Union Pacific one summer during college as rodman on a survey party and returned to Union Pacific upon graduation as a surveyor. Later he transferred to Omaha, where he served in several capacities in Bridge and Architectural departments until his appointment as Fire Protection Engineer in 1978. He was appointed Manager, Fire Protection in 1987. As Manager, Fire Protection, he directs or coordinates all company fire prevention and protection programs and serves as technical advisor on fire related matters to all company activities in the 20-state, 21 000 mile railway system. Roger is the chairman for the National Fire Protection Association's (NFPA) Railroad Section, which represents railroad fire protection professionals. He served as the editor of the chapter on "Railroad Fire Protection" in the current edition of the NFPA *Fire Protection Handbook*.

THE JIAGEDAQUI FIRE MANAGEMENT PROJECT (JAIPRO): AN EXAMPLE OF INTERNATIONAL ASSISTANCE

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ABSTRACT

As a result of a series of exchange visits between Canadian and Chinese forestry officials during the period 1974-81, the Canadian International Development Agency undertook a project for the delivery of technical aid in the form of a model forest fire management system in northeastern China. The Ontario Ministry of Natural Resources' Aviation and Fire Management Centre has been engaged as the Canadian Executing Agency for the JAIPRO Project. The project covers the full spectrum of fire management activities. In dealing with their Chinese counterparts and when traveling to China, project advisors have had to learn new skills and adapt to unfamiliar conditions. The project, now in its fifth year of operation, is beginning to show positive results, however, changes often come slowly and it may be some years before the full benefit of the project is realized.

INTRODUCTION

In the post-cultural revolution period, China's leaders put forward a grand concept to develop the economic strength and raise the standard of living of the country to the level of advanced western countries by the early part of the 21st century. This program, referred to as the Four Modernizations, gave strategic priority to agriculture (which includes forestry), energy, transportation, and education. To help realize these goals, the Chinese have adopted an "open door" policy in the hope of expanding economic and technological exchanges with foreign countries.

Between 1974 and 1981, a series of exchange visits by various Canadian and Chinese groups identified forestry as a high priority area for Canadian technical assistance to China. Further exchanges sponsored by the Canadian International Development Agency (CIDA) led to the development of a project to form a model forest fire management system in the Daxinganling Region of Heilongjiang province in northeastern China. The project, centered in the region's largest city Jiagedaqui, has been given the acronym JIAPRO for Jiagedaqui Project.

THE FIRE PROBLEM IN THE PROJECT AREA

The JIAPRO area is located in the extreme northeastern portion of China, where the main feature is the Daxinganling (Great Xingan Mountain Range). The project area is mostly located in Heilongjiang province with a small portion of the southern part being in the Inner Mongolia Autonomous Region. The forests in the area are under the management of the Daxinganling Forest Corporation (Fig. 1), whose jurisdiction spans from 50°10′ north latitude to 53°40′ north latitude and ranges from 122° east longitude to 126°30′ east longitude. The eastern and northern boundary of the area is the Heilong River, which forms the international boundary between the People's Republic of China and the Soviet Union. The size of the Daxinganling area is approximately 8.4 million ha.

Fire Environment

The terrain, typical of the Xingan mountains, has elevations in the northern portion of the area ranging from 450 to 1100 m. There are many drainages with wide grassy valley bottoms. During the spring

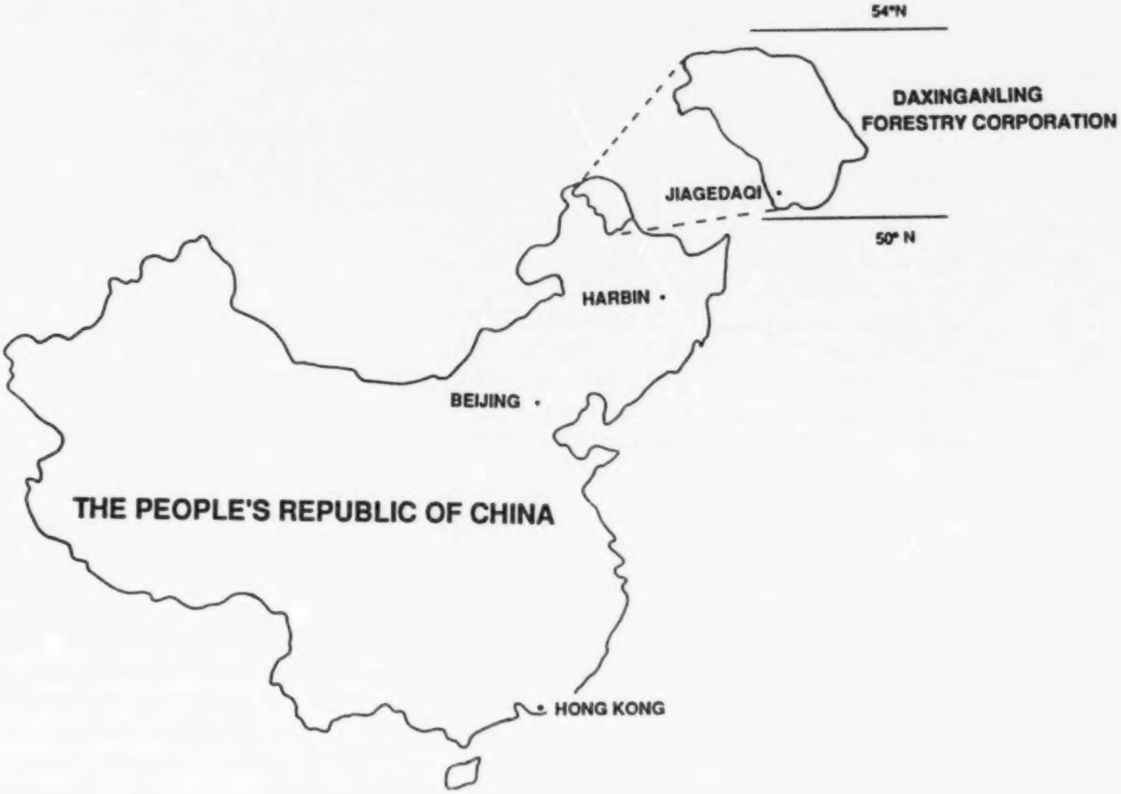

Figure 1. The Peoples Republic of China showing the area administered by the Daxinganling Forestry Corporation.

fire season, these valley bottoms are dry and most of the creeks are without water.

The climate of the Daxinganling Region is just what might be expected at a latitude of 50° north. It is very cold, and the mean average annual temperature is -30°C. The climate is continental; cold-temperate characterized by long, cold, dry winters and short, warm, humid summers (Fig. 2). Springs are invariably dry and windy. Relative humidities during the day fall to the range of 15 to 20%. Wind speeds in excess of 60 km/h occur frequently and are a major contributing factor to the fire problem in the area. Summer brings warm weather and significant rainfall. As a result, the summer period is generally not considered to be a fire season *per se*. The fall period is characterized by quickly declining precipitation and relative humidity levels. Fall fire weather is significant but does not approach the severity of the spring period.

The forest cover varies considerably from north to south. The northern three-quarters of the region is almost entirely forested and is approximately 70% coniferous. The dominant species is Korean larch (*Larix dahurica*), with some Scots pine (*Pinus sylvestris* var. *mongolica*), white birch (*Betula platyphylla*), and spruce (*Picea koyamai* var. *koreansis*). Poplar

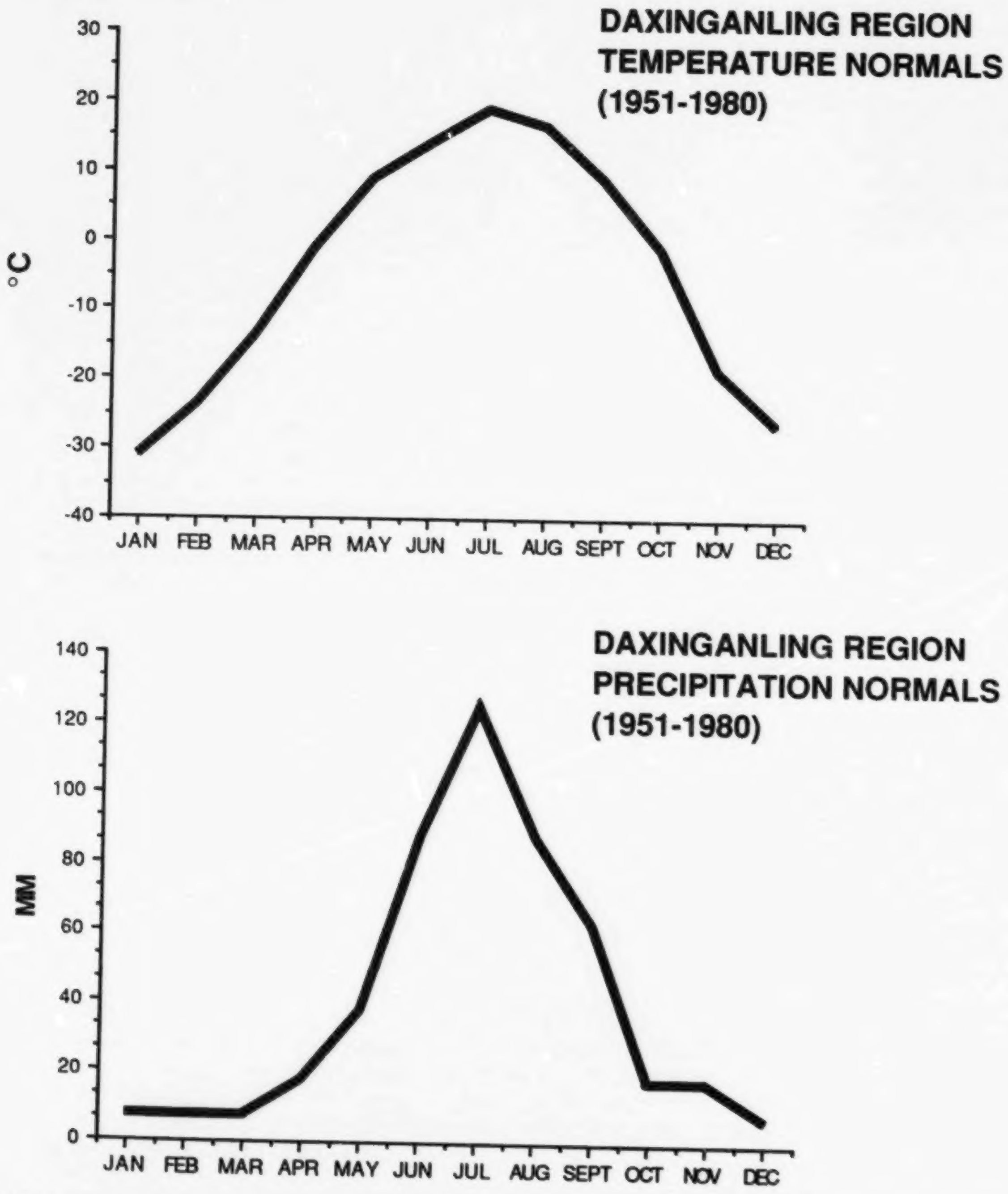

Figure 2. Thirty-year temperature and precipitation normals for the Daxinganling region in north-eastern China.

(*Populus* spp.) and oak (*Quercus* spp.) species make up a small proportion of the remaining forest cover.

As a result of over-harvesting and repeated extensive wildfire, natural larch stands have virtually disappeared in the southern portion of the Daxinganling and have been replaced by oak and birch scrublands. The oak does not lose the last year's foliage until the next year's greening, making the entire area extremely flammable during the spring and fall when grass and leaves are in a cured state. There are numerous larch and Scots pine plantations established throughout the south. These plantations seldom achieve much growth before the area is again devastated by wildfire.

Fire Occurrence

Because of the summer rains, the area has two very distinct fire seasons (Fig. 3). The official spring season is the period from March 15 to July 15 and the fall season is from September 15 to November 15. Fire activity generally begins in the southern part of the project area in the latter part of March, and the activity progresses north as the snow melts.

Daily fire occurrence is relatively low. There are few days on which multiple fires occur. Historic fire records indicate that typically 60-80 fires occur each year. In his study of fire occurrence during the 10-year period from 1975 to 1984, Lynham has shown that 23% of the fires were due to lightning, 46% were people-caused and 31% were attributed to unknown causes[1]. Lynham's study notes a predominance of people-caused fires in the southern portion of the region. Most of the lightning-ignited fires occur in the north. Concentrations of people-caused fires were also seen in the center of the area in close proximity to the main north-south railway line. The main causal groups identified were railway, industrial, mushroom pickers, hunters, fishermen, and beekeepers. Many fires are

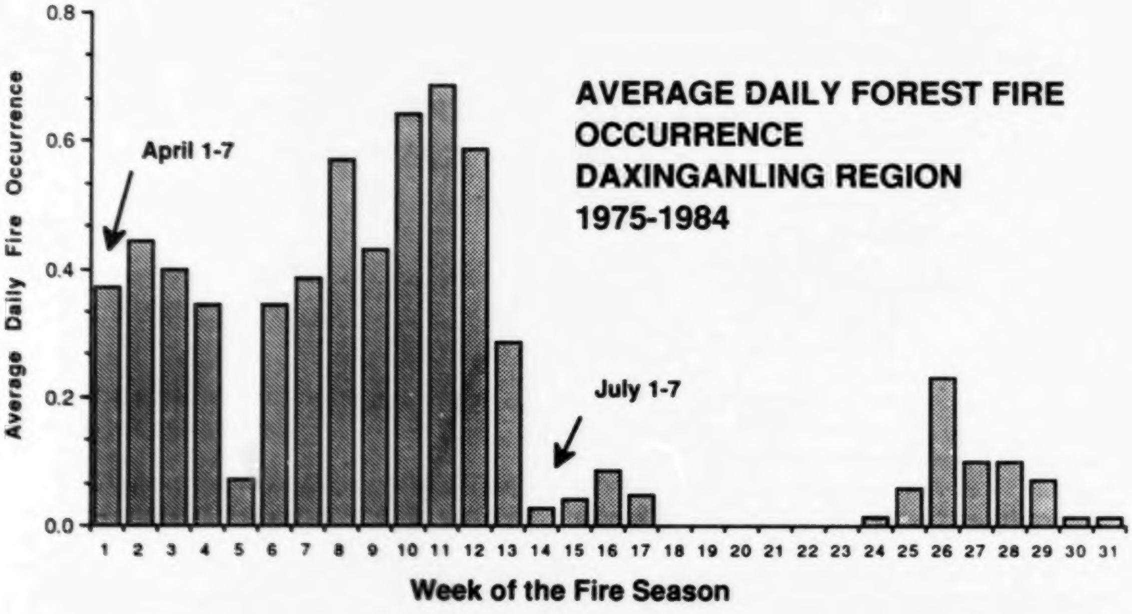

Figure 3. Average daily forest fire occurrence in the Daxinganling region of northeastern China for the period 1975-84 (includes all causes of fires).

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[1] Lynham, T.J. 1987. Forest fire occurrence prediction in the Daxinganling Forestry Management Bureau, Heilongjiang Province, China. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Project, Sault Ste. Marie, Ontario.

caused by seasonal, transient workers who migrate into the area from southern China to pick mushrooms or to tend colonies of bees. Smoking materials are thought to be a major source of ignition.

THE EXISTING FIRE ORGANIZATION

The fire organization in the region is decentralized[2]. There is a central fire center in Jiagedaqui that has overall coordinating responsibility for fire activities in the region. The region is divided into 13 bureaus. The responsibility for initial attack and operational fire suppression activities rests more directly with local bureau headquarters. The decentralized nature of the region is complicated by the fact that there are a number of organizations that are only loosely connected, each of which has some responsibility for the fire control effort in the region.

The Forest Police Brigade is a large (over 2000 fire fighters), paramilitary organization that provides much of the initial-attack capability in the region. Until recently, this organization functioned quite independently of the regional fire control center in Jiagedaqui. The role of the forest police includes enforcement of fire prevention rules. They often take part in organized ground detection patrols as well as providing suppression forces for ongoing fires. The brigades in Jiagedaqui and in the more northern city of Tahe provide initial attack using helicopters. Forest police brigades seem to be more actively involved in bureaus that do not have a fully developed administrative organization.

In organized bureaus, the bureau staff has responsibility for delivery of the fire program. Local organizations differ slightly in numbers of staff; however, a typical bureau headquarters would have a staff of approximately 100 persons involved in fire control activities. This staff would include the necessary management staff, towermen, check station attendants, and approximately 50 professional fire-fighters. Bureaus are supported by several cooperating groups. In ShiBaZhan, for instance, there are approximately 700 forest farm workers trained and available in case of fire. An additional 500 forest farm workers who have had less training are also available if needed. Other groups who often contribute fire fighters to the effort are the railway company and the military.

A third organization in the region is the Northeastern Air Forest Protection Brigade (NEAFPB). It has responsibility for aerial fire control actions. It runs the aerial detection program and operates the helicopters. Until very recently, this organization seemed to do these things quite independently of the fire center.

The Daxinganling fire center has the overall coordinating responsibility for fire control operations in the region. In the past, this responsibility was given but was accompanied by little authority. Activity seems to have centered around organizing fire fighters and transport from neighboring bureaus to assist when a fire escaped control and gathering information to pass to various higher levels of the bureaucracy.

All of these organizations have been neither anticipatory nor proactive in their approach to the fire problem. Little is done until a fire has been reported. Detection in the area is carried out through a combination of lookout towers and aerial detection. Prior to 1988, the tower system consisted of 30 towers. The towers have been poorly located in many instances, have not been equipped until recently with adequate firefinders, and in most cases have no overlapping coverage. Aerial detection is accomplished using the Transport 5 model aircraft. This is a Russian designed biwing aircraft that is relatively slow. Patrol routes are fixed and are not adjusted to meet changes in fire danger. The average fire size at detection is 60 ha.

Fires continue to expand and often become very large before initial-attack forces arrive. Water bombing is not feasible in the area due to the lack of suitable water sources. Some chemical bombing was done in the past, but this does not seem to be practiced at present. The region is serviced by four helicopters. These are based at the airports in Jiagedaqui and Tahe. The helicopters are the Mi-8, a twin-turbine helicopter of Russian design. It can carry up to 25 passengers or 18 fire fighters with equipment. The large size makes it unsuitable for landing in many remote locations. Fueling can only be done at airport locations. Road access is also limited, and it is not uncommon for fire fighters to have to walk for 4-5 hours and in some cases several days to reach a fire or their assigned portion of the line. Thus, fire suppression is delayed and small fires develop into large, campaign fires.

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[2] Jin, Ke Chan. 1985. Forest fire prevention and management, Daxinganling Forestry Management Bureau. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Centre, Sault Ste. Marie, Ontario.

Suppression methods are mostly direct attack with a variety of hand tools such as blowers, branches, swatters, and backpack pumps. Daytime fire intensity is often such that fire fighters cannot work effectively on the fire's edge. Night fire-fighting is the rule rather than the exception. Indirect attack, burning out from roads or natural barriers, is used on many occasions.

One resource the Chinese have in abundance is manpower. Historic fire records often indicate suppression forces in excess of 10 000 men. One thousand men will be dispatched to a 100-ha fire. Estimates of the number of men committed to the disastrous fire runs of May 6, 1986, were as high as 50 000. Fire fighters are organized into crews of 20 men. They travel lightly, each man carrying his fire fighting tool, rations for several days, and perhaps a blanket for sleeping. Indications are that often the groups will be accompanied by a rifleman who will provide further food.

THE PROJECT

The project began with the fire season of 1984. It was planned to run for a 5-year period until the summer of 1989. In the initial planning missions to China[3], it was quickly recognized that an improved fire management capability in the area would require the development of an organization that could adequately plan for and respond more quickly and effectively to fires as they occur in the area. The stated objectives of the project are

> To provide a framework or building blocks for China to strengthen her fire management capabilities; and to develop a centralized fire control system with the center at Jiagedaqui.

The fire problem in the project area, as is usually the case, is not a result of one factor but is the consequence of a combination of many things. The design of the JIAPRO project reflects this and is multifaceted, covering the broad spectrum of fire management activities. Recognizing that the immediate priority should be to develop systems that would allow for early detection and a rapid initial attack, there has been an effort to concentrate on those things that will assist in the development of an efficient initial-attack force.

The Ontario Ministry of Natural Resources (OMNR) was chosen as the Canadian executing agency for the project. Staff from the OMNR have been heavily involved in the implementation of the project along with advisors from other agencies. Forestry Canada has provided much of the advice in the fire intelligence component of the project. The Alberta Forest Service provided the advisor for the detection component. Private consulting firms have played a role in the communications component.

A detailed plan of operations was drawn up at the beginning of the project[4]. This plan has provided the framework for delivering the project. The plan identified a number of components and detailed expected outputs from each component.

Organization and Operational Planning

The decentralized nature of the organizations involved in fire control operations in the project area was quickly recognized as a major stumbling block to efficient fire operations. It was recommended to the Chinese that they embark on a program to strengthen the role of the fire center in Jiagedaqui and to bring together, in a more formal and direct reporting relationship, the several organizations responsible for fire operations in the area. The Chinese have been moving toward this end over the past 4 years. Although organizational changes of this nature are difficult to implement, we have noted a much closer liaison between the various organizations and a more-defined authority for the fire center when dealing with other work units.

Major changes are difficult if those at the top of an organization are not fully committed to the change. Cultural, political, and technological differences between the eastern and western worlds make it difficult for the Chinese hierarchy to envision the end goals of the project. Canadian tours and exposure to Canadian fire management techniques have been an important part of the project. Three groups of leaders from the Ministry of Forests in Beijing and the Daxinganling Forestry Corporation were brought to Canada during the summers of 1985, 1986, and 1988 to give them an overall appreciation of fire management as it is applied in Canada and to promote the vision of what can be accomplished in China.

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[3] Goodman, J.F.; Kourtz, P.H. 1982. Report of the Canadian forest fire technical mission to China. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Centre, Sault Ste. Marie, Ontario.

[4] Ontario Ministry of Natural Resources. 1985. Plan of operation: Jiagedaqui model forest fire management project. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Centre, Sault Ste. Marie, Ontario.

Identified in the organizational component of the project was the need to train a fire center manager. During the summer of 1987, this training was carried out at the OMNR's regional fire center in Thunder Bay. During his Canadian study, the Chinese manager prepared a comprehensive table of contents of a fire operation manual for the Daxinganling fire management area. A major output from this component of the project was the establishment of a modern fire center in Jiagedaqui which has the necessary intelligence collection, display, and communications systems to allow for effective central planning. The fire center has been established in a new building and has been equipped with many of the necessary features. During the spring fire season of 1988, daily planning was initiated. Planning sessions with fire center staff were carried out twice each day, and although information is still limited and communications systems still require development, this has been seen as a substantial step forward to achieving the goal of centralized fire management within the region.

Detection

The detection component was split into two parts—tower and aircraft detection. The emphasis of the project has been to assist the Chinese in improving the tower detection program, particularly in the areas of communications and the concepts of seen-area mapping. A Chinese trainee from each part of the component has been trained in Canada. At the beginning of the project, there were 30 operating towers in the region. Many of these towers did not have communications. Few had any kind of a firefinder. Tower locations were often established for reasons of convenience, and seen-area mapping had never been done for any of the towers. The tower detection program that is evolving in the project area is showing improvement in these areas. The system in place at this time leans toward a tower detection system supplemented by aerial detection patrols.

Communications

A prerequisite to effective fire management in the project area will be an adequate radio communications system. This component was seen as fundamental to the success of the project. The objectives are to establish an operational VHF radio network in the area so that voice communications can be established from locations throughout the area. Engineering for the network was subcontracted to a private communications firm. Two Chinese communications technicians have been trained by OMNR staff in the installation, operation, and repair of the necessary radio communications equipment. Over $1.2 million have been spent on Canadian-manufactured radio communications equipment. Installation of the network has begun. Communications advisors from OMNR participated in initial installations during the summers of 1987 and 1988. Because some difficulties have arisen with the frequencies assigned to the communications system, some of the equipment that had been purchased and sent to China was returned to Canada for modification.

Suppression Systems and Training

The foundation of an effective suppression system is a well-equipped, properly trained fire-fighting force. The aim of this component was to introduce suppression techniques based on rapid initial attack. The approach has been to train a few individuals who could then take their knowledge back to China and provide the necessary training to the large numbers of professional fire-fighters in the region. Seven forest police brigade supervisors were brought to Canada during the summer of 1986. During their 6 months in Canada the trainees were instructed in the basics of fire fighting as it is applied in Ontario. They were provided with sufficient training to bring them to the level of an OMNR initial-attack fire boss. While receiving this training, the opportunity arose for the trainees to spend some time actively involved in the attack on a project-sized fire in northwestern Ontario. Four of the seven also traveled to Hinton, Alberta, where they received training and were qualified in the techniques of rappeling. A training manual for the JIAPRO area has been completed.

As a further part of this project component, one person was trained in the maintenance and warehousing of equipment. The Chinese have built a new warehouse in Jiagedaqui to house the equipment supplied by Canada as well as Chinese-provided equipment. A small amount of fire suppression equipment has been purchased for evaluation by the Chinese. Fifty power pumps, 40 000 m of 3.8-cm diameter hose, three all-terrain vehicles, 10 chain saws, 250 backpack pumps, and some additional hand tools have been purchased and placed in the project area.

Fire Intelligence Systems

Key outputs from this component were identified as the development of a fire danger rating system for the project, the installation of a network of fire weather stations, the preparation of fuel type maps, and the initiation of computer technology in the fire center to aid the duty officer in preparing a strategic plan for each day of the fire season.

At least three different fire danger rating systems had been in use in the Daxinganling region. Although it has been difficult to obtain information on how these systems work, it would appear that they are all limited in the quality of their output. Forestry Canada fire research personnel have shown that the Canadian Forest Fire Weather Index (FWI) System will work in this area of China and has recommended its use[5]. During the spring of 1986, six fire weather stations were operating in the project area. The fuel moisture codes and fire behavior indexes of the FWI System were calculated daily for each of these stations and were used by fire center staff. The staff also continued to use a fire danger index that is prepared daily by the local arm of the national weather service. A simple fire occurrence model has been recommended for use in the project area[6].

As a part of this component of the project, a weather technician has been trained to provide briefing services to the fire center and to operate the weather observation network. The project plan calls for the establishment of a 16-station weather observation network. To date, eight of these stations have been installed and equipped with Canadian equipment. A fire weather operations plan has been prepared for the project area. Obtaining adequate weather forecasts has been a problem. The Chinese national weather forecast service does not routinely forecast relative humidity (RH), making it difficult to make fire danger forecasts. Negotiations have been initiated with the local office of the weather service to include RH in forecasts and also to improve the timing of the forecasts so that they will better meet the needs in forecasting fire danger. To date, little progress has been made in these negotiations.

One individual has been trained by Forestry Canada at the Petawawa National Forestry Institute, Chalk River, Ontario, in the techniques of producing enhanced, forest fuel type maps using satellite information. A complete mosaic using enhanced winter imagery of the project area has been produced.

The project has purchased a microcomputer for use in the Daxinganling Fire Centre. The computer is Chinese-made and will produce output using Chinese characters. The computer operator has developed a program to calculate and forecast the indexes of the FWI System and a data base to record fire weather and fire danger information.

Aircraft Management

Two trainees were selected for this project component, and they traveled extensively in Ontario, Alberta, and New Brunswick throughout the summer of 1985. During this exposure, they were able to observe the use to which aircraft are put in fire operations in Canada.

Prevention

The majority of the fires in the area are of man-caused origin. A project staff member has received training in Ontario. The emphasis has been on the development of an organized approach to fire prevention in the project area. Currently a fire prevention plan is being prepared.

Postgraduate Studies

The project has sponsored two Chinese students at the University of Toronto. These individuals were enrolled in the diploma program in resource management. The two students attended university for a 2-year period. During the summer of 1987, one of the students was employed as a fire fighter on an OMNR unit fire crew. The other student was trained in fire intelligence.

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[5] Stocks, B.J.; Lynham, T.J. 1987. Suitability of the Canadian Forest Fire Danger Rating System for use in the Daxinganling Forestry Management Bureau, Heilongjiang Province, China. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Centre, Sault Ste. Marie, Ontario.

[6] Lynham, T.J. 1987. Forest fire occurrence prediction in the Daxinganling Forestry Management Bureau, Heilongjiang Province, China. Unpublished report on file with JIAPRO Project, Ontario Ministry of Natural Resources, Aviation and Fire Management Project, Sault Ste. Marie, Ontario.

SPECIAL CONSIDERATIONS WHEN DEALING INTERNATIONALLY

A project of this nature yields many challenges. There are, of course, the technical challenges of adapting systems that work well in one country to the conditions of another country. There are also many personal challenges for advisors working in a strange setting and with people who have a vastly different cultural background.

Language has posed significant problems throughout the life of this project. Few of the trainees speak English. None of the Canadian advisors speak Chinese. A cadre of interpreters was selected and trained for project work. Speaking through an interpreter is a learned skill. An advisor must master the ability to package thoughts into small units before speaking through the interpreter. Although the interpreters assigned to the project are quite fluent and skilled in the English language, misunderstandings often arise. Interpreters speak textbook English. Jargon and colloquialisms can cause difficulties. One misconstrued word near the beginning of a conversation can divert the attention of the trainee so that the entire conversation loses value. Attempts to clarify a point have often led to further misunderstanding, and on occasion, several hours have been spent in clearing up a simple point that one would normally expect would take only a few minutes to explain.

Living in China is different than living in Canada. Although the duration of most missions to China is not long (typically 7-12 weeks), advisors have had to adapt to the Chinese lifestyle. Accommodations are often spartan by our standards. Health standards and cleanliness are much lower than what most Canadians are accustomed to. Chinese foods (dog, donkey, sea cucumber, silkworm pupa) present interesting challenges. Similar adaptations must be made by Chinese who travel to North America. In most cases, one can adapt quite well. Some people do better than others.

Simple tasks seem to take twice or three times as long. Local bureaucracy and red tape is much more pronounced in China than it is in Canada. Something as simple as a long distance phone call can be a significant project. Waits of 4 or 5 hours to obtain an overseas line are not uncommon. The quality of the connection may be good or very poor. After waiting for several hours to establish a phone call, it can be quite frustrating when the line is lost before the end of the conversation. The seemingly small issue of obtaining service for a photocopier consumes a great deal of effort when one must package it and ship it over 1500 km to Hong Kong.

We have experienced problems with maintaining the services of Chinese project members. A little training goes a long way in effecting promotions and assignments to other jobs in an environment where there are few trained people. In several cases, we have completed the training of an individual and he was either promoted or left for another position, leaving the project back at square one.

The Chinese fire management system was and is far behind any system currently in operation in Canada. There has been very little directly related to fire management that has been of value to Canadians. Despite this, there have been benefits to the OMNR from participating in the project. Participation in the project has allowed us to broaden our horizons. It is useful to be aware of and to experience fire management as it currently is on the other side of the world. Project involvement has forced many of our staff into a very close and detailed examination of our own way of doing things. This has been useful. The personal enrichment received by many of our staff who have had this unique opportunity to travel and live within such a different culture has been of great value.

SUMMARY COMMENTS

The JIAPRO project is nearing its end. The current contract will expire in June of 1989. There have already been significant improvements in the Daxinganling region's fire protection system since the project began in 1984. Some of the improvements are due to the evolution of the original system, and others can be directly attributed to the input of the Canadian advisors. There are still many improvements to be made. The Chinese are interested in bettering the system. This interest has been heightened since the disastrous fires of May 6, 1987, when over 1.3 million ha in the north of the project area were destroyed by fire (Stocks and Ji-Zhong 1989) with a loss of over 190 lives and the destruction of 10 000 homes (*see* Fuchs 1988, Fig. 1). World interest has also turned to the fire problem in northeastern China. The World Bank has approved large loans which, along with China's own investment, will bring a large infusion of capital into the region (Fuchs 1988). This capital, along with the lessons learned in the JIAPRO project, should greatly assist the future development of a fire management system in the region.

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PRESCRIBED FIRE IN WIND CAVE NATIONAL PARK

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ABSTRACT

Total protection from fire through aggressive suppression has changed the ecological balance of the ponderosa pine-mixed grass prairie complex of Wind Cave National Park. Because fire has been determined to be a vital force in maintaining the natural composition and distribution of plant communities, it is necessary to consider the use of prescribed fire as a substitute for the unwanted man-caused and natural fires that can no longer be allowed to burn within the Black Hills. The success of reintroducing fire is attributed to information derived from research, the cooperative efforts of affected various land management agencies, effective public relations, participation by ranchers, and management of both wildfire and prescribed burning activity. Since 1973, Wind Cave National Park has expanded its prescribed fire program from small ground ignition plot burning of 100-150 ha to present-day sophisticated aerial ignition unit burns of 1000 ha. This has provided an opportunity to gain a better understanding of the effect of fire on vegetation and ungulate grazing patterns and preferences, as well as the potential for fire to enhance surface water flows.

INTRODUCTION

The concept of prescribed burning within the U.S. National Park Service (NPS) is a relatively new idea. The NPS from its creation in 1916 adopted a policy of aggressive fire suppression. All fires, whether natural or man-made, were suppressed immediately in an effort to protect and preserve the "natural" condition of the parks.

A significant body of data supporting the use and benefits of fire on certain vegetative communities was documented when in 1894, Captain G. H. Gale, commandant of the Fourth U.S. Calvary, was assigned to patrol the Yosemite area of California. Yosemite, by order of Abraham Lincoln in 1864, had become the first federally protected ecosystem in America. Gale observed in Yosemite that fire, rather than an enemy of mountain forests, was in fact a presence crucial to the forest's health, well-being, and survival. Research followed in the early 1920s by Chapman (1947) on fires in the U.S. Forest Service's (USFS) Southeast Region, applying the use of prescribed burning on longleaf pine (*Pinus palustris*) to determine reproduction and survival. Between 1931 and 1944 the Southern Forest Experiment Station published 26 bulletins and articles dealing with fire in the southeastern U.S. forests. Twenty years later in 1964, Richard Hartesveldt and associates began a series of experimental burns for Sequoia tree (*Sequoiadendron giganteum*) regeneration in Kings Canyon National Park (Murphy 1967).

By 1942 the USFS had initiated prescribed burning on the Southeastern Region national forests to perpetuate longleaf pine (Chapman 1947). Between 1949 and 1957 natural fires were allowed to burn over 25 400 ha within Everglades National Park. In 1958, Everglades was granted permission to use planned-ignition prescribed fires. Subsequent prescribed burning in 1959, 1960, 1963, and 1966 totaled 3898 ha and eventually led to an annual burning program within the park.

In 1968 the NPS policy underwent a radical change from one of total fire suppression to one of fire management (Kilgore 1975). There were a number of reasons for this change including the Leopold report on wildlife management in the national parks (Leopold et al. 1963). Based on the success of the fire programs in Everglades and Sequoia-Kings Canyon national parks and the research efforts of both private and public organizations, the NPS updated its policy of total fire suppression to a three-part program of fire management in 1968. The new program established a policy of letting some natural fires burn when they did not threaten human life or developed properties. It recognized prescribed burning as a proper tool of forest management and recommended continued total fire suppression when required.

Fire has historically been a dominant factor in the biology of North American plant and animal communities. This is especially true of the grassland communities. Periodic fires, started naturally by lightning or intentionally by plains-dwelling people, maintained the vegetation in an early successional stage of development and was a critical factor in determining the fluctuating boundary between prairie and pine forests of the west. With the advent of fire control measures at the turn of the century, fire was, for the most part, excluded from these areas. This led to the increased spread of forest and shrub cover in grassland associations. Locally, this resulted in the rapid expansion of ponderosa pine (*Pinus ponderosa*) stands throughout the Black Hills of South Dakota at the expense of the mixed-grass prairie.

HISTORY OF FIRE IN THE BLACK HILLS

In the Southern Hills region of South Dakota, ponderosa pine tends to spread into surrounding grasslands along the pine-grassland ecotone (Gartner and Thompson 1972). Prolgulske (1974) very effectively illustrated this through comparison of photographs taken by W.H. Illingworth during the Custer Black Hills expedition of 1874 with photographs of the same sites taken a century later. The increased forest cover noted in 1974 was attributed primarily to the lack of thinning by natural fire. Prolgulske and Shideler (1983) further enunciate the environmental significance of fire in the Black Hills region.

Ponderosa pine forests under natural conditions burn every 10-25 years throughout their range in the western United States (Weaver 1967; Wright 1978). At Wind Cave National Park (WICA), personnel have used dendrochronological techniques to find that the fire cycle varied between 13 and 21 years from 1820 to 1910. These fires generally did not kill mature trees but instead burned the litter layer while killing young pines and other small-stemmed woody species (Weaver 1967). When wildfires are absent, due either to successful efforts at fire suppression or unusual regional climatic patterns, dense "dog-haired" pine stands result.

FIRE HISTORY OF WIND CAVE NATIONAL PARK

Wind Cave National Park is located in the southern third of the Black Hills of South Dakota. The 11 360-ha tract is a mixture of 80% grassland and 20% ponderosa pine forest. This vegetation supports significant numbers of grassland herbivores including bison (*Bison bison*), elk (*Cervus elaphus*), pronghorn antelope (*Anitlocapra americana*), and prairie dogs (*Cynomys ludovicianus*). The plants and associated wildlife form an important natural remnant of the original Northern Great Plains ecosystem and are a primary attraction to park visitors. The role of fire was described in park visitor brochures in 1928 in the following manner: "Fires constitute one of the greatest perils of the park..." and in 1964: "Fire is an enemy of the park forests and grasslands and of all the creatures that live in them." Such statements reflect the NPS philosophy of those times.

At least 82 lightning fires and 24 man-caused fires totaling 6250 ha were suppressed in the park from 1930 to 1987. Most were extinguished while small, but some burned across the boundary onto private ranches. The largest of these, a man-caused fire in September, 1964, burned 5475 ha of forest and grassland within 24 hours, including 3262 ha of private land. After an extensive public relations effort, including personal contact with adjacent ranchers by NPS personnel, prescribed burning was initiated at WICA in 1973 (Lovaas 1976; Shilts 1983). Partly for public relations purposes, the first prescribed fire created a fuelbreak along roads across an eastern portion of the park. Other prescribed fires included a series of small plot burns, followed by research burns, to present-day large-scale unit burning involving sophisticated aerial ignition equipment and the application of other technological information. To date, 26 prescribed fires have occurred in WICA totaling 3277 ha. In 1985 and 1987, two prescribed fires burned 376 ha and 996 ha, respectively.

RESEARCH PRESCRIBED FIRE

Dr. F.R. Gartner and his assistant W.W. Thompson, of South Dakota State University (SDSU), initiated modern use of prescribed burning in the Black Hills in 1970. They burned on private ranches in the foothills to evaluate fire for control of pines encroaching onto grasslands. The USFS commenced experimental prescribed burning in the Black Hills National Forest the following year.

In 1973, following a prescribed burning workshop sponsored by the South Dakota Division of Game, Fish and Parks, the Interagency Prescribed Burning Coordinating Committee was formed with representation from the USFS, Bureau of Land Management (BLM), NPS, SDSU, and Custer State Park. Through the committee, the land management agencies of the Black Hills were united in the promotion, use, and study of prescribed burning as a resource management technique.

The progressive application of experimental burning and the coordinated efforts of researchers opened the door for the numerous funded research studies which in turn established the foundation for the existing prescribed fire program at WICA. From 1973 through 1988, 10 research studies were carried out to ascertain the direct and indirect effects of fire on different resources in WICA. During the same period, management burning techniques were also developed.

Between 1972 and 1974, prescribed burning was studied as a range improvement practice in the mixed-grass prairie in western South Dakota (Gartner et al. 1978). The undesirable annual invader, Japanese brome (*Bromes japonicus*), was reduced in both yield and density by burning. Yield and density of western wheatgrass (*Agropyron smithii*), a dominant perennial, was generally increased by burning in the late winter or early spring. It was also noted that regrowth vegetation on burned areas was highly attractive to grazing animals and that burning had great potential for improving range in Japanese brome infested areas in western South Dakota.

During 1979 through 1981, a study was carried out on the effects of prescribed burning on ponderosa pine at WICA (Bock and Bock 1984) with emphasis in surface fuels and forest understory vegetation. The objectives of the study were 1) to determine if prescribed fires increased shrub and deciduous tree species in the forest understory; 2) to quantify mortality of immature pines in the forest-grassland ecotone, including both dense, spindly pine in the forest understory and seedlings and saplings invading adjacent grasslands; and 3) to measure the degree to which prescribed fire has consistent and creditable effects throughout the study area. Study results indicated that burning reduced the densities of pine and *Ribus* spp., stimulated leadplant (*Amorpha canescens*), but had no significant impact upon densities of 10 other tree and shrub taxa. Nearly all pines less than 1.4 m in height were killed. Among taller pine trees, most mortality occurred in trees less than 5 cm dbh.

The 1979-81 study focused on the short-term effect of prescribed burning on vegetation as well as specific faunal responses to fire (Bock and Bock 1984). Two cool-season prescribed burns were conducted in 1979 (63 and 326 ha) to evaluate responses of breeding birds and deer mice (*Peromyscus maniculatus*) in pine forests and pine-grassland savannah areas in WICA. Both burns were relatively cool ground fires and only reached the pine canopy in isolated spots. Combustion of litter and fine surface fuels was nearly complete. Fourteen study plots, which included ponderosa pine stands of different densities and on different slopes and aspects, were utilized. Eight were burned and six served as control plots.

The prescribed burns reduced fuels, slowed pine invasion and recruitment, and temporarily improved habitat for one rodent and seven songbird species. In addition to deer mice, the American robin (*Turdus migratorius*), mountain bluebird (*Sialia currucodies*), solitary vireo (*Virego solitarius*), yellow-rumped warbler (*Dendroica coronata*), western tanger (*Piranga ludoviciana*), dark-eyed junco (*Junco hyemalis*), and chipping sparrow (*Spizella passerina*) were affected positively by the burns in the first postfire year. Overall effects of the two cool-season burns on vegetation were modest. There was a reduction in litter and young pine, but in general the forests and savannah appeared little changed. In contrast, the fires stimulated dramatic increases of deer mice and nesting birds during the first postfire summer, an effect that disappeared or even reversed itself by the second year. It is difficult to explain these results in terms of structural habitat modifications. Rather, it was suspected that deer mice and songbirds were attracted to the burn by some unmeasured temporary increase in the quantity or quality of their food supplies, perhaps stimulated by nutrient release or changes in soil temperature (Wright and Bailey 1982). Such temporary increases of birds and small mammals on one-year-old burns have been reported elsewhere (Ahlgren 1966; Lyon et al. 1978).

Coppock and Detling (1983, 1985) compared bison use of black-tailed prairie dog colonies before and after a prescribed burn on adjacent, uncolonized grassland at WICA. It has long been observed that bison are attracted to black tail prairie dog towns (McHugh 1958). Bison feed selectively on moderately grazed, grass-dominated areas just within the perimeter of prairie dog colonies. Such areas have a great concentration of more digestible and nutritious plants and greater accessibility of green tissues than vegetation grown in uncolonized areas (Coppock and Detling 1983).

Studies were conducted on 120 ha in the northwestern corner of WICA, which contained a prairie dog town and 84 ha of uncolonized grassland. The prairie dog colony contained plant associations that ranged from closely cropped grass-dominated areas (27 ha) in the outer margins to that of forb dominance in the center. A 4-ha prescribed burn was conducted in uncolonized grassland adjacent to the edge of the colony. The burn resulted in extensive reductions of standing-dead grass and litter (Bock and Bock 1984). Results indicated that bison cow-calf herds did increase their use of the burned site in the second year and decreased their use of the prairie dog colony (Coppock and Detling 1983). Burning has been demonstrated to enhance forage nutrient content, but effects may be minor and short lived unless followed by frequent regrazing. Bull bison were less attracted to the burn sites than cow-calf herds. Both cow-calf and bull groups tended to use the burned sites more in June prior to extensive greenup of warm season grasses; however, only the cow-calf herds consistently regrazed the burned site during the rest of the summer. Therefore, burning should be located a considerable distance from colonies to minimize bison impacts. Prescribed burning has been suggested as a useful tool in manipulating free ranging herds of large ungulates (Edwards 1984). Placement of planned burns in WICA should take bison foraging behavior and preferences into account.

During 1980, a 4-year fire ecology study was initiated to determine the effects of fire on birds and small mammals in mixed-grass prairie areas of WICA (Forde et al. 1984). The study area supports a wide variety of both tall and short grass species as well as warm and cool season grasses. Two study areas were chosen in 1980 in relation to prescribed burning activities scheduled for the spring of 1981. The Bison Flats study area consisted of 179 ha of mixed grass prairie, with short grasses prevalent as well as scattered ponderosa pine stands. The Red Valley study area, containing 499 ha, was dominated by cool season grasses. A few scattered trees were found in riparian sites. Transects were established in both study areas prior to the 1980 summer census of plants and animals. One control (no burn) and one burn transect was established in each.

Vegetation observations showed immediate reductions in density and numbers of perennial species and amount of dead material present after burning. These, however, showed increases 2 years later (Forde et al. 1984). Bare ground percentage increased immediately after the fire, indicating a loss of protective cover for birds and small mammals. The study further found that bird and small mammal populations quickly adjusted to the fire-altered habitat and that these adjustments appear only temporary and continue to change as the vegetation recovers from burning. The conclusion that grassland species are adapted to fire and have been historically subjected to it further substantiates the need for prescribed fire at WICA (Forde et al. 1984).

Brizuela (1987) studied the effects of fire on prairie dog diet and dog town vegetation (i.e., canopy structure and species composition). He noted significant changes immediately following burning but specified that differences in prairie dog diet and plant community structure and composition had all but disappeared within one year. He also noted that prairie dogs were more likely to feed and/or colonize on burned versus unburned areas.

Krueger (1988) examined the effects of fire on the physical structure of the grass-forb canopy-prairie areas in the park. She found that responses to burning, so significant for less than 1.5 years, were really identical when comparing under-grassed and moderately grassed areas. The responses studied included resilience of canopy structure, number of canopy layers, and relative percent of live and dead vegetation.

TECHNOLOGICAL INFORMATION

Currently the park utilizes the Administrative and Forest Fire Information Retrieval and Management System (AFFIRMS) (Helfman et al. 1980) and the BEHAVE program (Andrews 1986), both common to most agencies involved in wildland fire management. AutoCAD, published by Autodesk, Inc., is a popular computer-aided-design (CAD) program originally designed for use with IBM-compatible microcomputers. It is primarily used for storing drawings in a computer recognizable format but also has the ability to store information concerning the drawing as well. At Wind Cave National Park, AutoCAD has several applications, including fire management. Maps are created that highlight the locations and perimeters of fires. AutoCAD can then be used to calculate area burned. This and other information (such as the fire's name, the date of the fire, fire weather, etc.) can be stored in the drawing and used later to produce custom maps. For instance, a map showing all areas that burned between the years 1980 and 1988 can easily be produced. Fire-related maps can also be inserted into vegetation or fuel model maps to illustrate the effects of fire in the park.

In cooperation with the USFS's Intermountain Fire Sciences Laboratory, at Missoula, Montana, a Fire Effects Information System in the form of a computer program has been compiled and formulated for ready access to the fire effects information and interpretation system at WICA. Such a program provides the user with the means to quickly and easily interact with an exhaustive, refined, and expertly interpreted knowledge base that includes all of the known and reliable information on the effects of fires on the plants and animals in the user's working area. A similar system has already been developed for the BLM. It covers the grass and shrubs for the Great Basin region of the U.S. and is currently in the hands of users for review and refinement. The early results indicate that the system represents a revolutionary advance in access to fire behavior and effects information. Its use should allow for safer and more effective prescribed burning.

CONCLUSIONS

Fire management is the most aggressive form of resource management in national parks. Prescribed fire and wildfire, with their associated suppression impacts, have the potential to drastically alter parks for many years. Resource management agencies have in recent years become acutely aware of the need to evolve into fire management programs based on a clearer understanding of ecological principles involved in fire management. Coordinated fire research, in association with technological information, has been found to be vital to the resource management program at WICA.

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APPROACHES TO WILDFIRE CAUSE DETERMINATION

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ABSTRACT

This paper, dealing with the current status of wildfire investigation in the United States, is based on the observations and experience of the author. The approaches to wildfire investigation today range from near nonexistent to excellent depending on the level of commitment by the line officers and staff on any given unit. Direction, training, and investigative expertise are the primary factors that determine the success or failure of a wildfire investigation. This paper discusses the reasons for the lack of consistency throughout the country and solicits support and guidance for the future direction of wildfire investigation in the United States.

INTRODUCTION

There are currently no national standards, prerequisite qualifications, or certification for wildland fire investigators. The success or failure of a fire investigator is dependent largely on the abilities and experience of each individual investigator. There are three primary reasons for wildfire investigation within the U.S. Forest Service. First, there is generally a great deal of manpower, expense, and effort expended to prevent wildfires. Without an accurate determination of the specific causes of wildfires, the wildfire prevention strategy may be misguided. As an example, the incidence of incendiary fires reported has steadily increased over the past 10 years. This is due in part to the investigator's ability to accurately determine the point of origin and thus the fire cause (USDA Forest Service 1977-87).

Secondly, criminal prosecution is a consideration in most wildfires investigated by the U.S. Forest Service. Causing brush, trees, or grass to burn, allowing a fire to escape control, or leaving a campfire without completely extinguishing it are some of the more common criminal prohibitions that can lead to a maximum $U.S. 500 fine, 6 months in jail, or both. Persons without authority who wilfully set wildfires face a maximum $U.S. 5,000 fine, 5 years in prison, or both.

Thirdly, civil lawsuits often result from wildfires in which monetary damages are awarded. The U.S. Forest Service has statutory authority to bill for costs of suppressing wildfires where negligence is involved. Utility companies, railroads, and individuals reimburse tens of thousands of dollars annually to the U.S. Federal Treasury. Fire investigations also serve to protect the government's interest when suit is brought for property loss.

BACKGROUND

The first formal wildfire investigation training program was developed by U.S. Forest Service special agent Bill Longacre in the early 1960s. Although Longacre's program was oriented, in part, to the western states, it serves as the nucleus of present wildfire investigation training. Currently, the training has been expanded to cover all major fuel types (burn patterns), cultural aspects of fire causes (southern states), motives, case preparation, and arson investigation.

The complexity of a wildfire investigation depends on many factors and the circumstances in which a wildfire occurs. Wildfire investigation can be as simple as determining lightning as the cause or it can involve months of detailed investigation to bring about an arson conviction. The size of the fire, costs involved, damage to private property, sufficiency of evidence, actions and intent of the responsible party, judicial workload, and management commitment are some of the considerations relating to fire investigation.

Statistical fire causes inside the national forest protection boundary are reported annually in the National Forest Fire Report published by the U.S. Forest Service. Representative of the 10-year average fire starts, the 1986 National Forest Fire Report lists the following statistical fire causes by percentage: lightning, 52.6%; arson, 15.1%; campfire, 9.3%; miscellaneous, 8.0%; debris, 5.1%; smoking, 3.9%; equipment use, 3.6%; children, 1.5%; and railroads, 0.9%.

FIRE CAUSES

Smoking, campfires, burning debris, equipment use, railroads, and children are all statistical fire causes that can be solved by an experienced fire investigator. Usually negligence or carelessness is involved. Failure to correct equipment deficiencies, perform proper maintenance, or follow prescribed fire prevention practices or regulations is often the case. Generally, these types of fires are determined by evidence found at the origin and the cooperation of persons responsible.

Incendiary fires in the national forests is second only to lightning in terms of fire occurrence and acreage burned. The expertise required to investigate incendiary fires requires a strong background in fire investigation, law enforcement training, and a working knowledge of the legal system.

The motives associated with arson are varied. The high incidence of incendiary fires in the southeastern U.S. are generally termed as cultural. Wildfires in these states have been used for generations to clear vegetation for hunting, to rid areas of snakes, chiggers, and other insects, and for other forestry related practices.

Generally, the motives for incendiary fires can be categorized as revenge/grudge, vandalism, vanity, concealment of other crimes, profit, and emotionally disturbed. Pyromania and thrill-seeking are included with emotionally disturbed.

ELEMENTS OF THE FIRE INVESTIGATION

The measure of a successful fire investigation is dependent on its ability to withstand the scrutiny of the court. In other words, all evidence collected must be lawfully admissible in court with the burden of proving what caused the fire resting squarely on the shoulders of the investigator. The responsibilities of the investigator encompass a wide variety of technical expertise that includes origin determination, cause determination, photography, collection and preservation of evidence, interviewing, forensic science, and administrative and judicial procedures.

FIRE INVESTIGATION TRAINING

Two annual wildfire investigation trainings are currently offered. The Federal Law Enforcement Training Center (FLETC) at Glynco, Georgia, has offered an 80-hour wildfire investigator training course since 1981. This course is sponsored by the U.S. Forest Service and U.S. National Park Service. The course has a capacity for 30 students and is attended primarily by employees of federal agencies with wildland fire responsibilities. In 1989, wildland arson investigation will be incorporated into the program.

The Boise Interagency Fire Center (BIFC) in Boise, Idaho, has offered a 40-hour basic fire investigator course since 1985. This course is a condensed version of the FLETC training.

Both courses offer field training in fire cause and origin determination, interviewing techniques, forensic laboratory capability, collection and preservation of evidence, courtroom testimony, and report preparation.

Many states and federal regions receive the basic fire investigation course locally upon request. The FLETC 80-hour arson training course will be available to other regions of the country in 1989 as well as being offered at the training center.

DISCUSSION AND CONCLUSIONS

The ability to bring a fire investigation to a successful conclusion is based primarily on the individual investigator's ability, fire and investigative experience, and training. Factors such as the complexity of the investigation, criminal and civil ramifications, and fire cause are not always considered when a fire investigator is requested.

The national red card rating system provides for qualifications and certification in all fire-related positions except the fire investigator position.

It would seem that the costs associated with large fires alone would necessitate the need to identify and utilize the best fire investigative expertise available. It has been the purpose of this paper to solicit the support needed to establish fire investigator and arson investigator positions at the level of expertise required. Fire size class and suspected cause would dictate the identification and utilization of the red-carded fire investigator position.

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THE INTEGRATION OF FIRE CONSIDERATIONS INTO FOREST/LAND-USE MANAGEMENT: AN ILLUSTRATION

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ABSTRACT

Integrating fire management considerations into land management plans will vary from detailed, complex fire analysis to rather general and simple direction depending on the magnitude of the fire programs and problems on the land managing unit. The Payette National Forest, in central Idaho, utilized the National Fire Management Analysis System (NFMAS), the flexibility designed in the current U.S. Forest Service (USFS) Fire Policy, and present wilderness fire plans to develop a varied fire program that integrates with designed flexibility into the USFS National Forest Planning Process. Two fire plans currently exist authorizing prescribed fire use from unplanned ignitions—the Frank Church-River of No Return Wilderness Fire Plan and the Lake Fork Fire Management Area Plan. Both areas are managed by the McCall and Krassel ranger districts of the Payette National Forest. The general land management objectives for these areas are: 1) reduce natural fuel accumulations in order to reduce the spread and intensity of future wildfires and their associated short- and long-term costs; 2) maintain fire-dependent ecosystems; and 3) maintain and enhance plant succession to increase forage palatability. Each unplanned prescribed fire area has a set of prescription elements and a monitoring and evaluation plan to assist in making the decision as to whether a fire should be designated as prescribed or wild. In addition, those situations which result in an unplanned prescribed fire being changed to wildfire status are also documented. An Escape Fire Situation Analysis (ESFA) is completed on all prescribed fires which exceed prescription and are subsequently declared wildfires. Extended use of prescribed fire from unplanned ignitions to other designated management areas of the Payette National Forest will result as the successful implementation of the existing plans are gradually realized.

INTRODUCTION

Prior to 1978, the Payette National Forest fire management program followed the National Forest Service direction which was known as the 10:00 a.m. fire policy. This policy stated that all new fire starts would be controlled by 10:00 a.m. the next day. With all wildfire operations, suppression was emphasized generally without regard to cost or resource values-at-risk. This policy sometimes led to aggressive fire suppression which was often in direct conflict with resource objectives. Revised national policies and land management planning has enabled fire managers to develop more flexible fire programs placing more emphasis on resource values, the natural role of fire in the environment, and evaluation of the cost of the suppression effort. It is now a program that responds more than ever to resource management objectives.

BACKGROUND

As a result of the U.S. Forest Service national fire planning effort in the early 1970s, the agency received much higher funding in order to strengthen the number and types of fire resources. It was generally thought that increased funding would provide for increased success of the suppression effort resulting in less area burned. The theory of additional funding aiding the fire suppression effort was partially correct. More money did facilitate more organized and better trained crews and provided for additional and updated suppression equipment, but it was not overly successful in reducing area burned. During this same time period a handful of biologists and ecologists were stressing the importance of the environmental role of fire in wildland ecosystems, but the majority of fire managers were still emphasizing suppression of all fire starts. *Modification in policy in 1971 led to permitting* lightning-ignited fires in designated wilderness areas to freely burn, under carefully specified conditions, where an approved fire management plan had been developed (Towle 1985). These fires were classified as prescribed fires. Generally, however, the only wide use of prescribed fire during this period was for the disposal of logging slash.

As the 1970s were coming to an end, the aspect of fire's costs and benefits were being more objectively analyzed by all fire managers. In 1978, a new national direction in the U.S. Forest Service was enacted to provide better integration of fire protection needs into the national forest land management planning process and help control suppression costs (Nelson 1979). The objective of wildfire suppression was changed from one of control of all wildfires by 10:00 a.m. to one of managing fire suppression costs and damages, consistent with land and resource management direction and values. This new policy also opened new doors for increased use of prescribed fire both from planned and unplanned ignitions to meet resource objectives.

The following definitions of terms from the current fire policy will be used in the remainder of this paper (from USDA Forest Service 1984).

Appropriate Suppression Response: The planned strategy for suppression action (in terms of kind, amount, and timing) on a wildfire which most efficiently meets fire management direction under current and expected burning conditions. The response may range from a strategy of prompt control to one of containment or confinement.

Confine: To limit fire spread within a predetermined area principally by use of natural or preconstructed barriers or environmental conditions. Suppression action may be minimal and limited to surveillance under appropriate conditions.

Contain: To surround a fire, and any spot fires therefrom, with a control line as needed, which can reasonably be expected to check the fire's spread under prevailing and predicted conditions.

Control: To complete the control line around a fire, any spot fires therefrom, and any interior islands to be saved; burn out any unburned area adjacent to the fire side of the control line; and cool down all hot spots that are immediate threats to the control line, until the line can reasonably be expected to hold under foreseeable conditions.

THE PLANNING PROCESS

Concurrently with the aforementioned change in fire policy, the Payette National Forest was beginning its process of developing a Forest Land Management Plan according to the National Forest Management Act of 1976 and subsequent regulations for its implementation. The Act requires that the planning process fully integrates the various resource components of the management program, and that the criteria for designing and selecting alternatives be explicit. The planning process is an interdisciplinary fully integrated approach to decision-making. Issues and concerns are addressed by an intentionally broad array of management alternatives. The alternatives are evaluated against several explicit planning criteria in a process open to public scrutiny. The selected alternative is then converted into an annual operating plan and its implementation is monitored to ensure consistency with the planning criteria, standards and guidelines, objectives, and management area direction. The revised national forest fire management policy contains related changes—the fire management program must be cost effective and consistent with land management objectives[1]. Minimization of fire program cost plus the net value change in resource outputs has been specified as the cost effectiveness criterion (Mills 1983).

A National Fire Management Analysis System (NFMAS) for evaluating various aspects of a fire program was developed to assist fire managers in providing input to the planning process. This computer-based analytical system is an integrated analysis, as opposed to strictly a fire management analysis. It is used as an evaluation of multiresource or multifunctional programs to develop the most cost-efficient program mix, a composition of inputs such as initial attack forces or fuel treatment projects to reduce hazards purchased with a specified budget program level.

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[1] Dunlop, G.S. 1988. Concerning fire management policies within the National Forest System and the USDA response to fires in the western United States. Paper presented to the Congressional Subcommittee on Public Lands, National Parks and Forests, Committee on Energy and Natural Resources, United States Senate, Washington, D.C. (unpublished).

Fire and fuels management input to an individual forest plan varies throughout the National Forest System of the U.S. Forest Service. Some national forests have very detailed and rather complex direction in their plans while others selected a more simplified approach. Public response to the draft Payette National Forest plan showed that the proposed forest fire program was not a major issue or concern. With this in mind, the Payette National Forest selected a general approach in hopes of providing a flexible system to apply to the decision making process for fire evaluation (i.e., recognizing that fire is a very dynamic function juxtaposed with many other factors). Statements were developed that defined fire's goals and objectives, desired future condition, and standards and guidelines for the various aspects of the fire program (Fig. 1). More specific standards were developed for individual management areas where necessary. Other processes used to assist the Payette National Forest in developing input to the forest plan and specific fire management plans have been fire history and fuel studies throughout several forest management areas. These contracted studies[2] have provided historical fire and fuel data that assists managers in establishing area specific prescribed fire programs and projects for input to the forest plan.

The forest fire action plan is the latest document developed to compile the Payette National Forest's fire information. This document provides the specific "how tos" for implementing the direction and planning set forth in the forest plan. This more specific document will vary widely among national forests, but can be effectively used to isolate (either by reference or hard copy) an entire forest's set of fire manuals, guidelines, standards, fuels, management direction, etc.

IMPLEMENTATION OF FIRE POLICY

Implementation of the first Fire Management Area (FMA) under the new policy began on the Payette in 1979. The Lake Fork FMA Plan covers a 31 600-ha area, consisting of high-elevation timber types. The historical fire occurrence in this area was only about seven lightning-ignited fires annually, with most of these fires burning less than 1.0 ha each. The objectives of establishing this FMA were to allow fire to return to its natural role in the environment, reduce long-term suppression costs, reduce forest fuel accumulation, maintain natural and wildlife habitat succession mosaics, and provide fire managers an opportunity to "get their feet wet" in managing a natural fire program. Much of this area is quite visible from one of the larger residential communities in central Idaho.

The flexibility of the new fire policy was demonstrated on the Payette forest most dramatically during the 1985 fire season. The Savage Creek Fire burned 4905 ha of generally remote land but was interspersed with private ranches and commercially available high-value timber. The portion of the fire threatening private lands and commercial timber received a "control" suppression response. The head of the fire was not threatening private property or high-value timber and was spreading into high elevation remote land adjacent to wilderness. This section of the fire was managed under a "confinement" strategy using more natural terrain as designated boundaries. These different strategies served several objectives for this fire: 1) reduced exposure of fire-fighters to unsafe situations, 2) reduced fire suppression costs by an estimated 2 million dollars, and 3) reduced possible negative effects from suppression efforts on sensitive land types.

Another example of implementing the fire policy also occurred in 1985. At the same time the Savage Creek Fire was burning, the French Creek Fire escaped initial attack and eventually burned 5900 ha within the main Salmon River drainage. Several large areas of high-value ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) stands which were scheduled in the forest plan for future timber harvest were impacted by this fire. There were also sensitive watershed concerns just as there were with the Savage Creek Fire. This fire received a total control suppression strategy. An effective analysis process called an Escape Fire Situation Analysis (EFSA) was used by the District Ranger and the district's Fire Management Officer to evaluate the best alternatives in order to arrive at the decisions that were eventually made. Their decisions were reevaluated on a regular basis as the situation changed over the approximate two week period these fires burned.

In July of 1985, a second fire management plan was signed and adopted on the Payette National Forest. It was different in that it was in the largest wilderness area, the Frank Church-River of No Return

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[2] Completed by S.W. Barrett for the Frank Church-River of No Return Wilderness in 1984, the Rapid River area in 1987, and the South Fork of the Salmon River in 1988.

PAYETTE NATIONAL FOREST
FIRE MANAGEMENT DIRECTION SUMMARY

FOREST PLAN MANAGEMENT AREA(S) 2

WILDFIRE SUPPRESSION STRATEGY				PRESCRIBED FIRE	
Estimated CONTROL (%)	Estimated CONTAIN (%)	Estimated CONFINE (%)	Expected Avg. Ann. Acres Burned	Natural Fuels Acres/Decade Treated	Activity Fuels Acres/Decade and NIRP code
60	20	20	30	2600	NA

RESOURCE/FIRE MGT. EMPHASIS: Water quality for Rapid River Fish Hatchery, Wildlife and Livestock grazing. Fire emphasis is to reduce the risk of high intensity wildfires through the use of prescribed fire to reduce natural fuel accumulations.

CONSTRAINTS: No dozer use. Maintain water quality for the Rapid River Fish Hatchery.

FIRE INTENSITY LEVEL (FIL): Wildfires at the higher intensity levels will normally be suppressed.

SPECIAL AREAS: Paradise Cabin, Lockwood Point, Indian Springs, and Jackley Mountain Cultural Resource Sites. Rapid River Fish Hatchery (outside boundary).

PRESCRIBED FIRE USING UNPLANNED IGNITIONS: Limited use of unplanned ignitions in this area.

FIL	FLAME LENGTH
1	0 - 2'
2	2 - 4'
3	4 - 6'
4	6 - 8'
5	8 - 12'
6	12'+

Figure 1. An example of the fire management direction summary for a portion of the Lake Fork Fire Management Area of the Payette National Forest.

Wilderness (FC-RONRW), in the continental United States, was approved by Congress and signed into law by U.S. President Carter in 1980. It involved two U.S. Forest Service regions, six national forests, and twelve ranger districts and is 941 496 ha in size. Approximately 33% of the FC-RONRW are within the boundaries of the Payette National Forest. The plan contains a flow chart process (comprising many elements including weather, fuels, available resources, hazards and risks, socio-political concerns, etc.) that is used to evaluate each new fire start (Fig. 2). The purpose is to determine if the fire will be managed as a prescribed fire or as a wildfire. If a fire is managed as a prescribed fire, it will be accompanied by an incident plan which will include more detailed criteria than the initial review derived from the flow chart evaluation (Fig. 3). If the fire does not meet the criteria to be a prescribed fire, it becomes a wildfire and the most appropriate suppression strategy is the action taken. This could be a strategy ranging from *confine* with monitoring only, to *containment* of certain areas of the fire, to total *control*, or combinations of the three. Generally we have used the least cost alternative when taking action on wildfires in the FC-RONRW. An EFSA may also be written as part of the wildfire evaluation process. This process allows the District Ranger and the district Fire Management Officer to address alternatives that include resource values, hazards, risks, and projected costs to determine the most appropriate long range action for a wildfire.

STATISTICAL RESULTS

During the 1985-88 fire seasons, the Payette portion of the FC-RONRW burned 7700 ha from 35 lightning-ignited prescribed fires. During the same period, this area has burned over 48 500 ha from 85 wildfires with over one-half of this being burned during the 1988 fire season. The vast majority of the wildfires over this time period were managed under a confinement strategy with monitoring only. In 1988, personnel on the Payette National Forest also managed a complex 6000-ha fire outside of the wilderness area using a combination of control and confine to meet fire and other resource objectives. In comparison, during the 5 years prior to implementation of the wilderness fire plan (1980-84), the FC-RONRW only burned 83 ha from 56 wildfires. All of these fires received a full suppression response.

Costs for fire suppression are very high especially in wilderness and undeveloped areas where access and suppression strategies must be directed around airborne resources. The use of prescribed fire from unplanned ignitions is the preferred strategy for most wilderness fires on the Payette National Forest when the predetermined prescription elements can be maintained. This is not always the case and some fires may burn out of prescription and be changed to wildfire status and managed under the most appropriate wildfire strategy. Cost savings can be substantial if a confinement strategy can be used as opposed to control. In 1986, approximately 8000 ha burned within the Payette portion of the FC-RONRW. Twenty-five of the total 34 fires were managed under a confine strategy. The Intermountain Region office of the U.S. Forest Service estimates that the savings using this strategy was over 7 million dollars as opposed to having to control the same amount of area burned in wilderness. It is recognized that some of the fires would not have escaped initial attack and would therefore not have burned over the larger area. In 1987, two particular fires in the FC-RONRW escaped initial attack and were managed under confine and contain strategies rather than full control. Cost saving estimates totalled 1.7 million dollars. In 1988, only a quarter of a million dollars was expended on five wilderness fires that burned over 42 000 ha. These costs included containment action and burnout operations for protection of private and U.S. Forest Service structures. One of these fires started on June 25, and the other, July 11, and they are still smoldering at the time of this presentation. These two fires burned out of prescription and were reclassified to wildfire status and managed accordingly.

To date most of the savings have been derived from wilderness fires and EFSA considerations. Completion of forest plans and fire management action plans will further improve the outlining of initial attack strategies on all National Forest System lands managed by the U.S. Forest Service.

CONCLUDING REMARKS

The majority of the alternative methods of managing fires on the Payette National Forest have occurred in wilderness, however, we have identified through the planning process many areas throughout the forest where planned- and unplanned-ignition prescribed fires may be used to accomplish resource management objectives ranging from fuels reduction to range and wildlife habitat improvement. The Payette National Forest has a large compliment of expertise in fire management. It has been the development of this expertise that has allowed the Payette to be creative

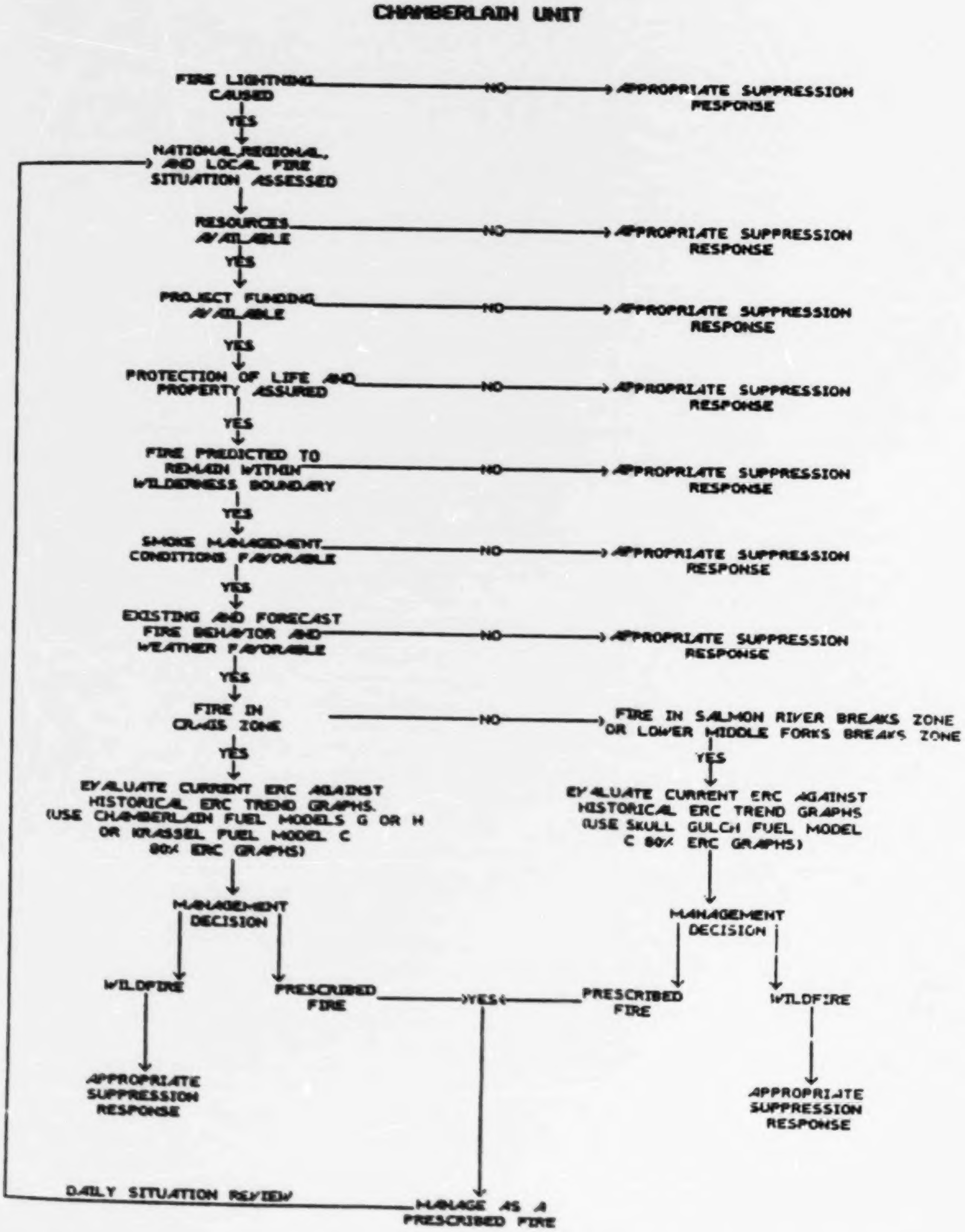
CHAMBERLAIN UNIT
FIRE LIGHTNING CAUSED
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
NATIONAL, REGIONAL, AND LOCAL FIRE SITUATION ASSESSED
RESOURCES AVAILABLE
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
PROJECT FUNDING AVAILABLE
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
PROTECTION OF LIFE AND PROPERTY ASSURED
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
FIRE PREDICTED TO REMAIN WITHIN WILDERNESS BOUNDARY
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
SMOKE MANAGEMENT CONDITIONS FAVORABLE
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
EXISTING AND FORECAST FIRE BEHAVIOR AND WEATHER FAVORABLE
NO
APPROPRIATE SUPPRESSION RESPONSE
YES
FIRE IN CRAGS ZONE
NO
FIRE IN SALMON RIVER BREAKS ZONE OR LOWER MIDDLE FORKS BREAKS ZONE
YES
YES
EVALUATE CURRENT ERC AGAINST HISTORICAL ERC TREND GRAPHS. (USE CHAMBERLAIN FUEL MODELS G OR H OR KRASSEL FUEL MODEL C 80% ERC GRAPHS)
EVALUATE CURRENT ERC AGAINST HISTORICAL ERC TREND GRAPHS (USE SKULL GULCH FUEL MODEL C 80% ERC GRAPHS)
MANAGEMENT DECISION
MANAGEMENT DECISION
WILDFIRE
PRESCRIBED FIRE
YES
PRESCRIBED FIRE
WILDFIRE
APPROPRIATE SUPPRESSION RESPONSE
APPROPRIATE SUPPRESSION RESPONSE
DAILY SITUATION REVIEW
MANAGE AS A PRESCRIBED FIRE

Figure 2. A fire management decision-making flow chart for a specific area within the Payette National Forest portion of the Frank Church-River of No Return Wilderness.

PRESCRIPTION EVALUATION

Fire Name ____________________Date and Time of Start_______ _______hrs.
Date and Time of Evaluation________________hrs.

TO BE COMPLETED BY DISPATCHER (ITEM 1-4)

(1) New Start?_____(If yes, attach fire detection and action report)
(2) Other
_____Increase in size from_____to_____acres.
_____Red flag warning predicted for______________________________
_____Smoke load becoming unacceptable
_____Increase in fire behavior
_____Adverse public reaction
_____Other (describe)____
(3) Appropriate Wx. Indicies: ERC_____ BI_____ FIL____ 1000hr____ Other__
(4) Monthly outlook for precipitation amount______________________

****

PRESCRIPTION GUIDELINES

		Yes	No
(1)	Person caused fire	___	___
(2)	Immediate threat to life or property	___	___
(3)	Threat to spread to suppression area (identify below)	___	___
(4)	Smoke load unacceptable	___	___
(5)	Red flag warning	___	___
(6)	Forest initial attack forces inadequate	___	___
(7)	Regional support forces inadequate	___	___
(8)	Other fires burning in management area	___	___
(9)	Adverse environmental effect predicted	___	___
(10)	Adverse public reaction expected	___	___
(11)	Funds for monitoring unavailable	___	___

If any of above "Yes," consider suppression.

****

Predicted Short-Term Fire Behavior

Long-Term Potential

Evaluation

Recommendation of Fire Behavior Committee

Record of Subsequent Reviews
(1) Prepare new evaluation if conditions changed.
(2) No change - enter date of review and sign.

Evaluation by_______________________________Date
Time____________ Signature

Figure 3. Prescription evaluation form used by Payette National Forest personnel in all fire management areas utilizing prescribed fire from unplanned ignitions.

with its fire program. Support from line officers, from the Chief of the U.S. Forest Service through to the forest's District Rangers, has been a significant part of the success of these new fire plans.

It needs to be mentioned that we have not come to where we are today without reservations, lost sleep, and several "gut wrenching" fire situations. We are still establishing our comfort levels and educating and involving our publics and forest users to allowing fire to return to a more natural role in the ecosystems we are responsible for managing in order to meet land use objectives and utilize alternative suppression strategies. It has not been by accident that we have received only minor negative response from the public and media for implementation of our fire program over the past 4 years. The public affairs and fire management personnel of the Payette National Forest have been very aggressive in getting ahead of the media power curve. It has always been our goal to provide them with straight-forward and up-to-date information about all aspects of fires burning in and out of wilderness. High priority is given to this task prior to and throughout the duration of the fire season. We recognize that our terminology associated with the different types of fire designations and suppression strategies can become muddled and confusing. Hopefully we will simplify this during the next major fire planning effort, but in the interim it cannot be stressed enough to those using different fire strategies to educate your publics and the media before they find some controversial aspect of your policies. It is very difficult to catch up once you fall behind the public and media power curve!

We will continue to aggressively initial attack the majority of fire starts on the Payette National Forest. Our analyses demonstrate and justify the need for the large and diverse array of fire fighting resources that are supported on the Payette forest for protection of the high-value commodity resources. Over time, however, the fuel must be managed or it builds up to the point that it becomes a major hazard, susceptible to large, unwanted fires. We cannot use timber harvest and other management practices on all areas in the Payette forest to manage the fuels. The use of fire combined with other land management practices can enhance wildlife habitat, create scenic mosaics, or reduce old growth timber stands that are often insect-infected and only serve as high fuel volume for the next catastrophic wildfire.

Any time fire is used as a land management tool, some risks are involved. The type of program being managed on the Payette National Forest is "high visibility-high risk". In a year of normal or high moisture, it may be difficult to achieve a desired objective. In a year of low moisture, fires may prove to be uncontrollable and burn beyond planned prescription. But if plans are thorough and your users and publics are behind you, and your decisions are based on sound documentation, you can have a successful program, even if some of the decisions are less than correct (fire management is, after all, not an exact science). We feel it is important that we make the best decision we can for any given situation; however, the key to success for this kind of program is a sound process for decision-making. It is also essential that this process is managed by highly qualified personnel, both as it relates to the "go-no-go" decisions and subsequent management actions once the plan has been implemented.

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RICK BELNAP is the Fire Management Officer for the Krassel Ranger District of the Payette National Forest at McCall, Idaho. Rick started with the U.S. Forest Service in 1964 as Fire Control Aid on the Payette National Forest. His fire experience includes suppression duties in nine western states. He served as a Division Supervisor and Operations Section Chief on a Region 4 Type 1 overhead team for 12 years. Rick has worked on four different districts of the Payette National Forest doing fire and fuels work. He has been active in teaching fire-related courses since 1968.

GENE BENEDICT is the Branch Chief for fire and recreation management on the USDA Forest Service's Payette National Forest which is headquartered at McCall, Idaho. Gene began his career with the U.S. Forest Service in 1961. Initially he worked as a civil engineering technician on the Payette and Boise National Forests. In 1967 he began a 4-year fuelbreak research assignment with Pacific Southwest Forest and Range Experiment Station's Forest Fire Laboratory at Riverside, California. In 1971 Gene transferred to the Cobalt Ranger District on the Salmon National Forest as the District Timber Management Assistant. In 1973 he moved to the Bridger-Teton National Forest at Jackson Hole, Wyoming, as the Fire Management Officer where he was instrumental in developing a large prescribed burning program and the Teton Wilderness Fire Management Plan. In 1975 he became the regional Fuel Management Specialist for the Intermountain Region of the U.S. Forest Service in Ogden, Utah. Gene was later transferred to the Northeastern State and Private Forestry section at Upper Darby, Pennsylvania, where he was Staff Specialist/Liaison for fire suppression, prescribed burning, fire equipment development, and air quality. In 1979 Gene returned to the Payette National Forest where he continues to supervise one of the largest fire organizations in the U.S. Forest Service. Since 1977, Gene has instructed on numerous occasions at the National Advanced Resource Technology Center in Marana, Arizona. He is currently a red-carded Incident Commander and has served in that capacity on two large and very complex project fires in Montana and Idaho in 1984 and 1985.

WORKSHOP SUMMATION

THE ART AND SCIENCE OF FIRE MANAGEMENT

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This meeting serves as evidence that the art and science of fire management is alive and well in Canada and the United States. For the practitioners, we hope the meeting provided welcome repose from the suppression duties of the fire season of 1988 and a chance to "see the forest through the trees." For the researchers, we hope this meeting provided an opportunity to get over the useless feeling that over came many of you this summer while the media pounded the fire management profession, often with poor information and half-truths. We seem at times to be our own worst enemy. A recent study at the University of Montana found that one-half of all prescribed fire managers in the Northern Region of the USDA Forest Service seldom consult fire researchers or nonforest service sources for any information to do their job.

Our Canadian hosts have done an outstanding job of organizing all aspects of this meeting. The program of topics was a comprehensive one. We started off with "Problems or Opportunities." Howard Gray, the moderator for the first session, was right on when he stated, "Problems are opportunities for the enlightened, innovative, and optimistic manager." The range of presentation topics gave us all a perspective of the complexity of fire management today:

- The urban-wildland interface
- Interagency cooperation and coordination
- What's "natural" or how do we manage for it
- Fire control on industrial forest lands
- Prescribed fire practices
- Wildland fire-fighter safety
- Rural fire-fighting programs

The second technical session presented fire research programs in support of fire management decisions and solutions. What's coming "down the pipe" is always interesting and the topics selected by the program committee were not disappointing. Each presentation from fire suppression to fire effects contained information needed by every fire manager in this day of limited budget and media coverage of fire events.

The session on the role of new technologies gave us a lot of food for thought. Larger applications, fire training, improved planning and logistics, fire weather forecasting, and spatial displays were all discussed in ways that had us all thinking about how far we have come in the profession and how much further we may have to go.

The fourth technical session presented fire management actions and practices. Given the previous sessions, this one was designed to present where we are now and what we are doing well. The urban-wildland fire problem can only get bigger, and interagency cooperation and planning presentations were fine examples of hard-working people trying their best to cope with the problem.

The organization and planning demonstrated in this meeting is encouraging. The profession needs innovative approaches, new technologies, and improved on-the-ground management if we are to meet the challenges of the future. This annual meeting and workshop of the Interior West Fire Council (IWFC) has provided a forum to present, discuss, and demonstrate our skills.

Perhaps even more importantly, this IWFC gathering provided an opportunity for researchers and practitioners to exchange and question ideas. These meetings help us all bridge the gap between the art and science of fire management. In the discussions over drinks, over dinner, and riding on the bus, you've been building bridges: bridges between researchers and practitioners, between agencies and industry, and between art and science. Discussing issues and exchanging ideas was beneficial to all involved; this open exchange must continue.

This is one of the real strengths of the IWFC. The exchange between researchers and practitioners is critical if we are to do a better job of developing technologies useful in training personnel and developing research for getting the job done. Professional interaction and the sharing of experiences is also critical if we are to effectively respond to issues in natural resource management that are highly visible to the public.

The fires in the Greater Yellowstone Area in 1988 have prompted national public and political debate over fire management policies for national parks and wilderness areas. Our credibility as fire managers really took a beating while 0.6 million ha burned and nearly 120 million dollars were spent for fire suppression. Although the extreme fire weather and fuel conditions produced almost unstoppable fire behavior, the public held fire managers accountable for situations well beyond their control. Given these conditions, fire managers were still able to protect people's lives and to prevent the destruction of major park developments. It seems remarkable that over the season with more than 25 000 fire fighters working in the Greater Yellowstone Area, no fatalities occurred until October, when one was killed and another was critically injured by falling snags. And yet, the credibility of fire managers is still being questioned.

To be credible we must have the technical expertise to accomplish fire suppression safely and demonstrate our skill with prescribed fire applications. We must also recognize and cope with the political, social, and economic aspects of our jobs. Look at Yellowstone. At the center of the debate on fire policy we find a fire management plan that violates national written policy. How can one conduct a prescribed natural fire program with a plan devoid of written prescriptions that describe the required conditions under which fires may be allowed to burn? In this plan, there are no limits that aid in the wildfire-prescribed fire decision. It is interesting that many of the problems of this plan were pointed out by Dr. Bruce Kilgore at the 1982 meeting of the Intermountain Fire Council held in Jackson, Wyoming. Perhaps even more significant is the fact that the plan, written in 1986, is yet unapproved and unsigned by the regional director of the National Park Service. None of the interagency agreements concerning fire on park boundaries were signed either. All this for the largest prescribed natural fire program in the United States.

If you viewed the news of Yellowstone fires, you saw suppression forces clustered along the urban-wildland interface:

- Canyon Village
- Old Faithful
- Mammoth Hot Springs
- Grant Village

One of the Yellowstone fire management plan objectives was to prevent wildfire from destroying human life, property, historical and cultural sites, special natural features, or threatened and endangered species. With this objective, it is hard to believe that the Yellowstone plan contains not one single word covering fuel treatments and clearance about human facilities in the park. No wonder our credibility suffered when we can't be effective in fire management where people see it. Will the public trust our judgment elsewhere? Instead of having landscape architects designing aesthetic fire-safe treatments to carry out over years, we had hot shot crews do it in 2 days.

There are lots of challenges in fire management. At times we all feel as if we are standing on a shaking bridge all too close to the public snapping at our heels. To be effective and credible, we must be able to call a spade a spade. We all make mistakes and we should be able to say so. "CYA" documents do not increase our credibility. Attending and participating in meetings such as this one help us all. We must try to apply what we've learned here from the many fascinating formal presentations, the vendor exhibits, and the many informal discussions with others. We must each work to be technically proficient and innovative. We must seek to understand and anticipate problems before they occur, especially where the problems are social and political. Education and communication are keys to effective fire management.

This meeting gives us great optimism. The art and science of fire management is indeed alive and well, innovative and responsive. We look forward to seeing you all at the next meeting of the Interior West Fire Council.

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